POWER PLANT ENGINEERING

GENERATION - TRANSMISSION - DISTRIBUTION - UTILIZATION

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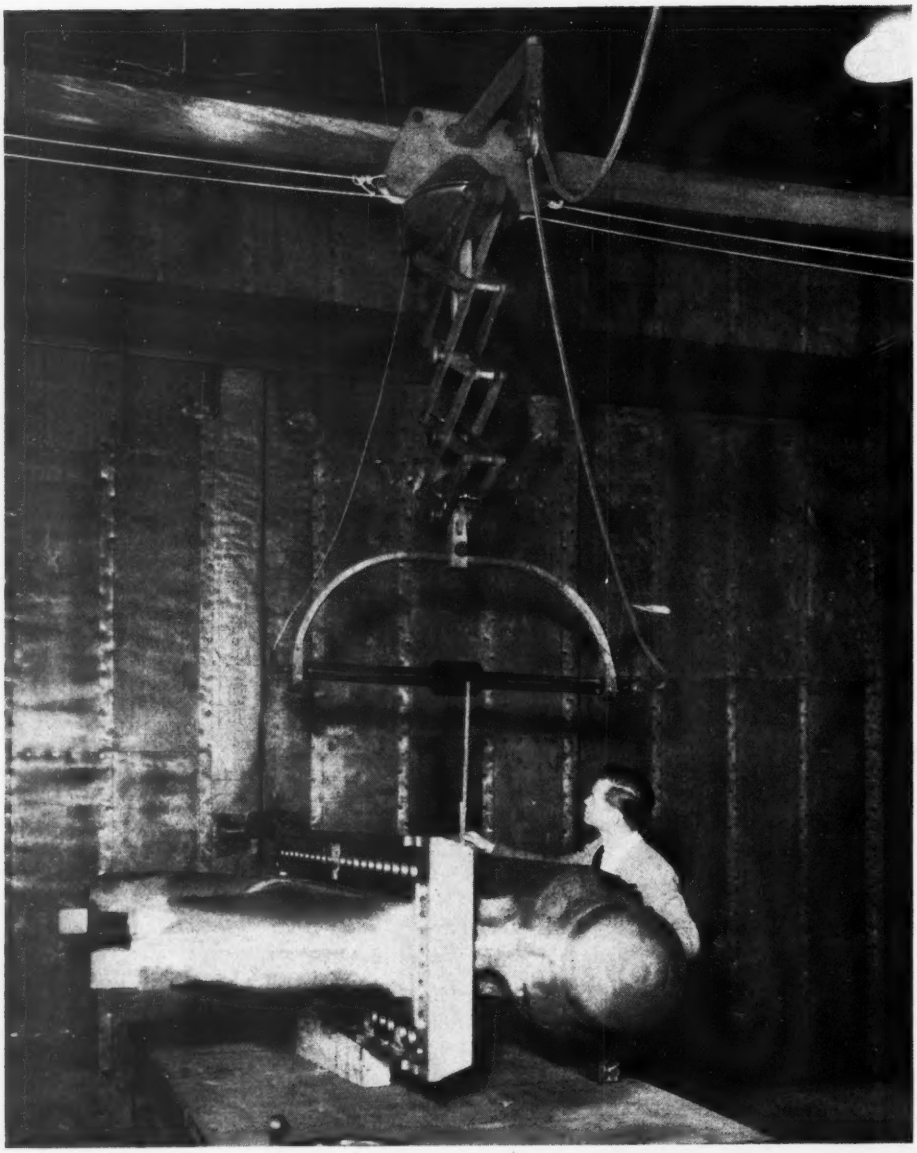


Radiographic examination of turbine steam chest in the lead-lined X-Ray room at the Schenectady works of the General Electric Co.

X-RAY LAZY TONGS

IN THE RADIOGRAPHIC examination and inspection of castings and welds, the problem of supporting and fixing the X-ray tube and leads in the desired position is often difficult. In this modern inquisition chamber the problem has been solved by means of these "lazy tongs." Constructed of kiln-dried wood and connected to a travelling crane of the same material, it enables the X-ray tube to be adjusted quickly and held in any position. The pantograph motion of the tongs allows a wide variation of heights for working with almost any size and shape of casting. In the photograph, the steam chest for a turbine is shown on the table ready to be X-rayed. ¶ This is typical of the care which is observed in modern manufacturing to insure perfect construction of equipment. A steel casting such as shown here often costs thousands of dollars, yet if the X-ray showed imperfections, even though these imperfections were not apparent in any other way, it would be rejected.

WITH THE EDITORS

What? No Coal!

PAPER MILLS without coal and power bills but with an excess of fuel and power to sell along with the paper or pulp output sounds like a nightmare of a harrassed coal or power salesman. It cannot be dismissed too lightly, however, and in the near future may cause drastic changes in the paper industry, changes which will have a far reaching effect on machinery, fuel and public utility fields.

The pulp process involves the separation of wood fibres by chemically removing the resinous substances which cements them together. This resinous material, carried away in the so-called black liquor, has a high heat value. Attempts have been made in the past, with more or less success, to recover the heat in this material as well as the unusual chemicals by burning in liquid form.

More recently a new process involving recovery in pulverized form has been developed by one of the best known engineers in the paper industry. The by-product fuel recovery runs well above the mill heat requirements. Commercial success and widespread application means cheaper paper but also means the replacement of millions of dollars worth of equipment, loss of market for millions of tons of coal. Even the public utilities will be affected not only because the output of hydro plants now operated by paper companies will no longer be needed by them but because all mills, including those now buying power, will be in a position to sell power produced as a by-product or in case this is impractical, sell an equivalent amount of pulverized fuel.

Air Pollution

FOR MORE than a generation laws have been on the books of many American cities governing the amount of black smoke a chimney is permitted to discharge into the atmosphere. As a result, marked development has been made in all classes of fuel burning equipment assuring smokeless combustion where this equipment is installed and properly operated. In addition manufacturers have invented and produced instruments that indicate and record the degree of smoke that exudes from the chimney. These have proved to be a distinct aid in reducing the smoke nuisance.

All this was done under the impression that the power and large heating plants were the major offenders in polluting the atmosphere. Such was probably the case in the early days of the agitation for smoke ordinances. It is noteworthy today, however, that modern power and large heating plants are extremely careful to operate with clear stacks and the study of air pollution is now turning to other phases of the problem, efforts being made not only to clear the chimneys of apartment buildings and residences by the use of more efficient combustion equipment and methods, but also to formulate laws governing the discharge of fly ash and obnoxious gases into the atmosphere.

To this end a project has been started in the city of Chicago to survey and analyze all phases of air pollution, extending from the sources and causes of every type of pollution to the ultimate effect on human beings. The program, as laid out, will require the services of a corps of experts for a period of about three years, and its findings will be of assistance not only to engineers but to law-making bodies.

In order to prevent air pollution by law, it has seemed necessary that scientists and manufacturers must first show how the nuisances may be eliminated without destroying the industry which has been the offender. In the power plant field, the smoke nuisance exists only where antiquated equipment and inefficient operations are tolerated by the owner and the community. The emission of fly ash, however, has not as yet yielded so thoroughly to practical methods of elimination but equipment is fast being developed for this purpose, the latest to be announced depending upon extremely high frequency sound waves. The elimination of sulphur fumes from the gases that reach the atmosphere, however, is a problem that has not as yet been solved in a way that has been accepted by industry as practical, but the problem is receiving serious consideration and with its solution the power plant could enter any community without being classed as a nuisance.

A Strong Comeback

A GENERATION ago the gas engine had a bright future. Improvements in the steam plant gradually pushed the producer gas plant out of the picture, and decline of the eastern natural gas fields left the gas engine an orphan except in highly localized areas.

Discovery of almost unlimited fields in the middle west and California meant little to the gas engine, however, until the spreading network of gas lines widened the area of utilization. Today with lines from the Texas Panhandle to Colorado, Kansas City, the Twin Cities, Chicago, Detroit, Indianapolis, Memphis and Atlanta, with local networks in California, Montana, and the Ohio areas, the nation is well served and prospects for the gas engine are again bright.

With an economy of around 10,000 B.t.u. per horsepower, the gas engine stands high in the efficiency ranks of prime movers. The engine also fits in well with low seasonal off-peak gas rates, for a number of companies have developed engines, convertible from gas to Diesel and back in as short a period as half a day, making it possible to use cheap gas in the summer months and switch over to oil in the winter.

MONARCH MILL Builds New Power Plant

Allied Paper Mills adds two 30,000 lb. per hr., 400 lb. boilers and one 2000 kw. extradition condensing turbine as part of electrification program in one of Kalamazoo's earliest mills

BECAUSE LARGE QUANTITIES of steam and power are required for process use, paper mills have always been leaders in the power plant field. As the trend toward industrial electrification progressed, the newer mills took advantage of improved heat balance methods and equipment, providing, of recent years, some of the finest examples of contemporary industrial power plant practice.

Faced with severe competition from these new mills, due to the lower production costs, the older mills have found it advantageous to modernize and to provide adequate power facilities. Kalamazoo, Mich., a paper center for generations, has, of course, many of these old mills, one of which, the Monarch plant of the Allied Paper Mills, is just completing a major modernization program.

Under the direction of Sargent & Lundy, Inc., of Chicago, the power plant is being completely rebuilt, requirements being such that the steam and power load about balance at 400 lb., 660 deg. F. throttle conditions and the heat balance arrangements provided are such that even the small amount of heat from the condenser circulating water is reclaimed for process use except for a few months in the summer.

The first mill on this site, known as the Kalamazoo, was built in 1867 and a section of the original stone wall is still in service. Another reminder of early days is a Dayton-Globe horizontal, double discharge water wheel over 40 yr. still furnishing power and carrying the Sunday load. Water is obtained from the mill pond formed by damming Portage Creek some distance above its junction with the Kalamazoo River.

Through the years the name was changed several times. The present mill, built in 1905, was taken over by the Monarch Paper Co. shortly after and in a consolidation about 15 yr. ago it became the Monarch Division of the Allied Paper Mills. Two paper machines are installed, about half the output of the mill being book, and the other half, coated paper.

The old power plant is of interest primarily as a means of emphasizing the change that has taken place during a single generation, in spite of newer equipment added from time to time, and to give a better understanding of the new plant design. In the old boiler room were eight 150 lb. vertical boilers fired by Murphy stokers and totaling 2500 b.hp. Three of these, one 400 and two 300 hp. units, were removed to make room for the new boilers. Three more will be removed soon, leaving the remaining two as temporary low pressure steam standby. Eventually these two will be replaced by a third 400 lb. unit.

Fuel and ash were handled by a Webster system. A belt conveyor transferred coal from a track hopper to a bucket elevator for delivery to an overhead bunker, or, to a 1200 t. inside storage immediately below the bunkers and in front of the boilers. This same V-bucket elevator served to reclaim the fuel from storage as needed. In the new plant this handling system is retained practically intact. The only change consists of adding a new 120 t. overhead bunker and reducing the coal storage to 900 t. in order to provide room for the new pulverizers. The steam jet ash conveyor, discharging to an outside elevated ash tank,

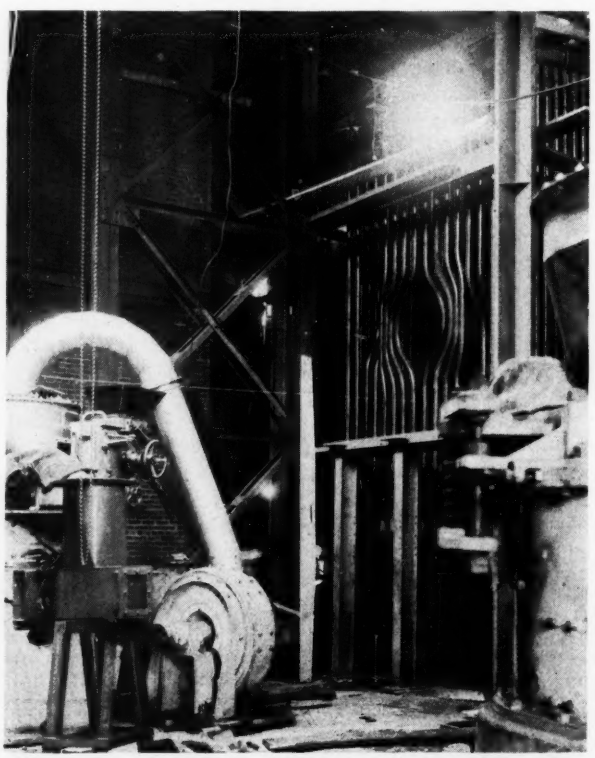


Fig. 1. One of the boilers under construction early in February. Each boiler is fired by pulverized coal from a 2 t. mill. A half ton impact mill is also provided for Sunday loads

also remains substantially the same except that the booster jets along the line have been replaced by a single jet at the tank outside, and branches have been added to take care of the new boilers.

In one end of the old engine room a cross compound Corliss, with a jet condenser, drives the beater line shaft through a rope drive while at the opposite end a cross compound Corliss also with a jet condenser, drives a 250 kw., 250 v., 370 r.p.m. d.c. generator in the same way. Additional electric power is furnished by an 18 by 36 in. non-condensing Corliss direct connected to a 200 kw., 250 v., 125 r.p.m. d.c. generator and a 300 kw., 250 v., geared turbine unit operating non-condensing at 6000 r.p.m. and driving the generator at 900 r.p.m. These last two units will be retained temporarily for standby service, but the first two engines will be removed as soon as the new turbine is in shape to carry the load.

An eight panel switchboard is provided for the generators and eight feeder circuits: 1, lighting; 2, engines and boiler room; 3, calenders; 4, coating mill; 5, water pumps; 6, soaking and rotary rooms; 7, No. 6 paper machine; 8, No. 5 paper machine.

water available in the pond. A 400 amp., 440 v. standby connection from the utility company has also been added to take care of lights, pumps and instruments over the week-end when the mill is not in operation.

The decision to locate the new plant in the old building rather than build a complete new plant was influenced not only by the central location and the fact that rebuilding is always cheaper than new building construction, but, by the fact that existing fuel and ash facilities could be utilized, and the old equipment retained for standby would be in an active plant where it would receive constant care and in emergencies both plants could be operated by the same crew. With a single turbine carrying the entire load without full utility standby, this matter of standby equipment is important.

With the old equipment occupying practically all the available space, locating the new plant was no easy problem. It was finally solved by placing the new turbine at the head end of the beater engine as shown by Fig. 4 and removing three old boilers and a portion of the coal storage. To do this and provide for the condenser and a 10 t. Whiting hand crane, carried on rein-

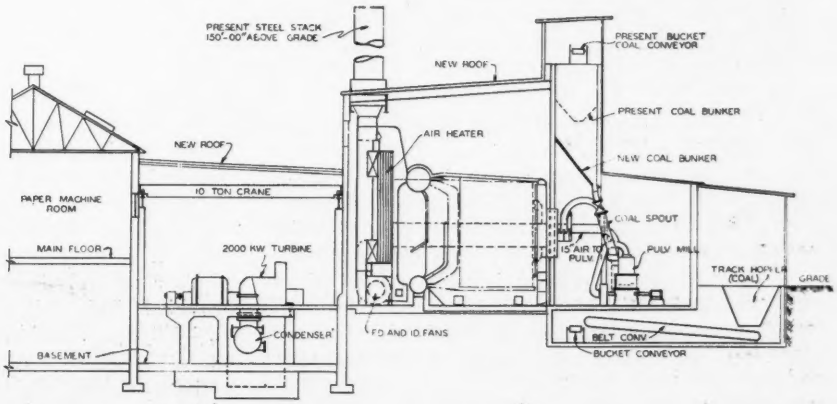


Fig. 2. Cross section of the new plant. The initial section includes two boilers, with a continuous steaming capacity of 30,000 lb. per hr. each, and one 2000 kw., 400 lb., 660 deg. F. condensing-extraction turbine. This drawing is Section AA of Fig. 3. A more detailed drawing of the turbine and boilers is shown by Fig. 7

Both paper machines have electric drive, the old 1200 r.p.m. m.g. sets consisting of 175 hp., 250 v. motors driving 115 kw., 250 v. motors. One of these sets is now being replaced by a new 1200 r.p.m., m.g. set, consisting of a Westinghouse 280 hp., 440 v., a.c. motor driving a 200 kw., 250 v. generator. The second paper machine will be rebuilt and the old m.g. set replaced by a new one as soon as practical after the new plant is running.

As soon after this as possible the old beater engine, visible in the foreground of Fig. 4, will be replaced temporarily by a 300 hp. synchronous motor, and the space now occupied by the steam cylinders will be used for a new 500 kw. Westinghouse set for taking care of the old d.c. power load. Eventually the synchronous motor will give way to individual motor drives, as new heater room equipment is installed. All new motors will be for 440 v. alternating current, thus eliminating transformers except for lighting. The lighting system is now a 220 v. two wire system. This system will be retained and connected to the new generator through a transformer with a double pole, double throw switch. It is the intention at present to use the water wheel for the lights and as much d.c. load as possible, depending upon the amount of excess

forced concrete columns poured in place, it was necessary to raise the old engine room floor 3 ft. and the roof 12 ft. The auxiliary basement level shown by the section Fig. 7 is at the same level as the old engine room floor. The condenser hotwell and hotwell pumps are in a pit below the basement level as shown dotted on the sectional drawing, Fig. 6. Boiler feed pumps are located on the basement level, in what will eventually be an open well adjacent to the turbine, while the condenser steam jet vacuum pump is on the operating floor both for operating convenience and space limitations.

The turbine foundation is concrete, the lower part entirely encased in sheet piling, because when excavating, a 2 ft. layer of top clay was found to overlay a 16 ft. vein of quick sand. To take care of this the turbine foundation plot was encircled by sheet piling, a foot of gravel was added to give proper drainage and the foundation poured on top of the gravel while the water level was kept down with a pump.

No circulating pumps are required because water from the mill pond is available under a 14 ft. head, more than sufficient to syphon the water through the condenser. In order to reclaim the heat ordinarily lost in the circulating water, provision is made to syphon

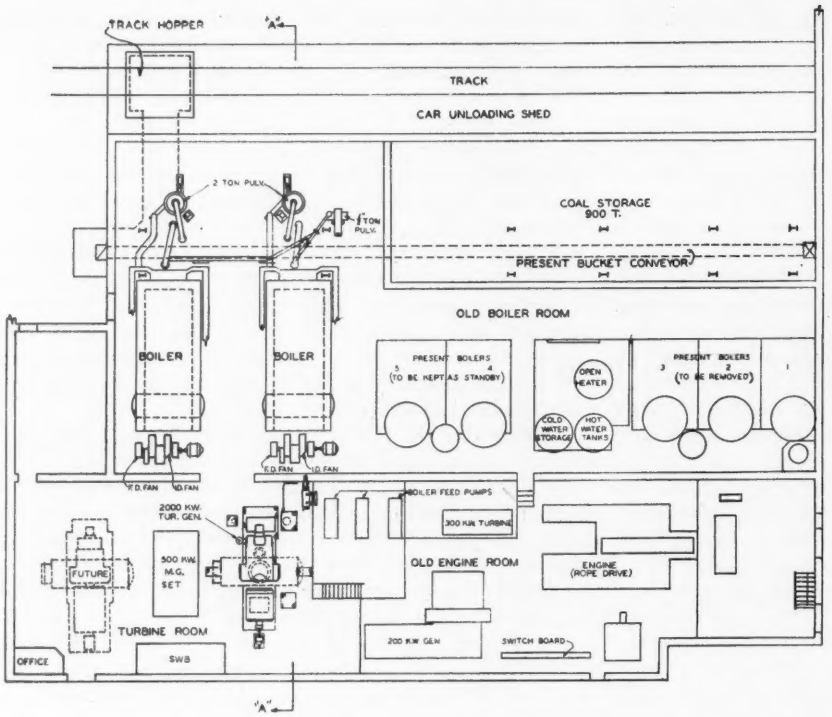


Fig. 3. Plan of the new station. Boiler feed pumps are located in the basement at the right of the turbine foundation and the feedwater heater softener and storage tanks in an auxiliary bay, now located between the two batteries of vertical boilers, but, when these boilers are removed and present plans for the new plant completed the heater will be next to the third new boiler. No circulating pumps are necessary as condenser cooling water is syphoned from the mill pond which provides a head of about 14 ft.

the condenser discharge to the mill filter intake in the winter months when the steam load is heavy. This provides complete heat recovery during these months, for though the steam flow to the condenser is small, the minimum heat recovered runs well over 5 million B.t.u. per hr. Under the average summer conditions the steam load on the boilers is estimated at 34,500 lb. per hr. of which 22,000 will be exacted from the turbine for process, leaving 12,500 lb. for the condenser. For average winter conditions, the total flow to the throttle will be 41,600 lb. per hr. of which 37,100 will be used for process and 4500 lb. per hr. to the condenser (this, however, is recovered as explained above). The electric load, in both cases, will average 1700 kw. but for extreme conditions is estimated to range from 1400 to 1900 kw.

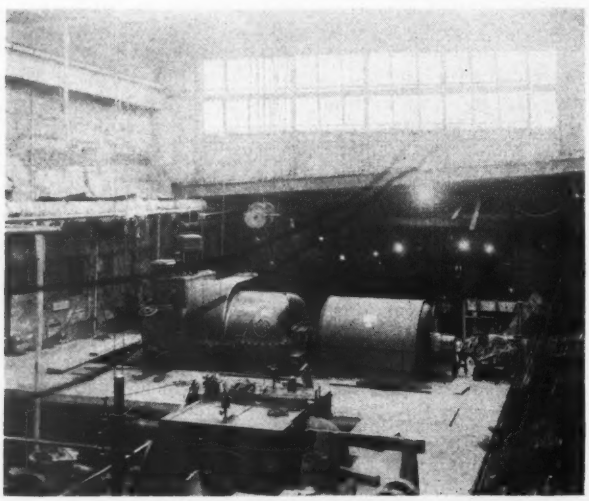


Fig. 4. The turbine room as it appeared early in February. The cross compound engine in the foreground now drives the beater room line shaft but as soon as the turbine is operating a motor will do this job and the engine will be removed to provide space for a 500 kw. m.g. set and for a future turbine as shown by Fig. 3. At that time a third new boiler will replace the two old vertical boilers being kept for low pressure steam standby and the power plant program will then be completed. The new plant is expected to be in service in March

To carry this load a new G. E. turbo-generator is provided. This unit consists of a 400 lb. ga., 660 deg. F., 3600 r.p.m. turbine driving a 2000 kw., 0.8 p.f., 3 ph., 60 cycle, 480 v. main generator and direct connected 250 volt exciter. The generator is provided with an air cooler in a closed system. The turbine is designed for 15 lb. ga. automatic extraction to the process lines and is protected against reverse flow by an Atwood & Morrell oil operated check. In order to provide a central point of control for operating convenience and emergencies, this extraction steam line feeds a manifold in the adjacent machine room, either direct or through a loop that runs past, and supplies, the deaerating heater and enters the other end of the manifold. From this manifold, branch lines supply different sections of the mill and these lines will be equipped with flowmeters as a check on operation and for cost allocation.

Set crossways of the turbine is a Westinghouse, two pass, radial flow condenser with 2000 sq. ft. of cooling surface made up of $\frac{7}{8}$ in. O.D. 18 B.W.G. tubes 14 ft. long. It is equipped with a twin 2 stg. steam jet air pump, with inter and after cooler, all located on the operating floor near the steam end of the turbine as mentioned previously. Two 30 g.p.m. condensate pumps driven by 3 hp. motors are located in the hotwell pit and pump through the steam jet coolers to the cold water storage tank as shown by the water piping diagram, Fig. 6. As explained earlier, no circulating pumps are necessary because water from the mill pond is available under a 14 ft. head. The gen-

erator air cooler and oil cooler are supplied from the same source, but for the steam jet emergency connection, the filtered mill service water is used.

Steam is supplied by two 450 lb. Combustion steam generators, Type VU, each with a continuous output of 30,000 lb. per hour, either one, with some low pressure help from the old boilers for extreme conditions, being able to carry the load in an emergency. Each unit has 4550 sq. ft. of boiler heating surface and 1330 sq. ft. of water wall surface on the sides, front wall, top and bottom of the surface. A 1320 sq. ft. superheater is designed to give a steam temperature of 675 deg. F. at full load.

Preheated air is provided for by a 2330 sq. ft. tubular air heater at the back of the unit immediately over the American Blower forced and induced draft fans on the operating floor. Both of these fans are driven by a single two speed Westinghouse 440 v. motor rated at 60 and 34 hp. at 1175 and 875 r.p.m. At the lower speed the forced draft fan has a capacity of 8,500 c.f.m. of 100 deg. F. air at 6.25 in w.g. and the induced draft fan 15,000 c.f.m. of 275 deg. F. gas at 2.98 in w.g. At the higher speed the capacities are 11,000 c.f.m. at 100 deg. F. and 11.35 in w.g. and 19,000 c.f.m. at 400 deg. F. and 5.23 in w.g., respectively. The low speed capacities are sufficient for normal output.

Boilers, with completely water cooled furnaces, as shown by Fig. 5, are baffled for three passes. The gases leaving the boiler outlet at the top, pass down through the air heater and to the induced draft fan, and upward through a vertical duct to the breeching and existing 150 ft. steel stack supported on the roof. The forced draft fan takes its suction from the floor level and discharges upward through the air heater. From the top of the air heater the hot air reverses and is brought about half way down the back of the air heater. Here the duct splits and runs around both sides of the boiler to the burner windbox in the front with a branch to the pulverizer for drying coal in the mill. The air heater is designed to give a temperature of 315 deg. F. at normal load.

Each boiler is normally fired from a 2 t. Raymond

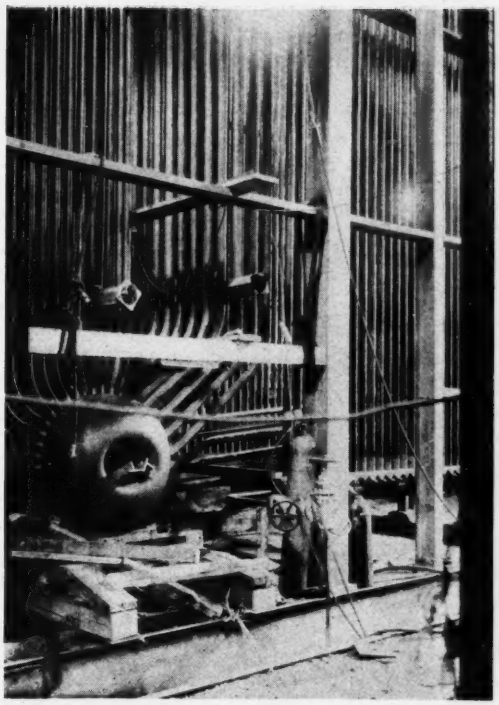


Fig. 5. Lower drum of one boiler showing tube and water wall arrangement

No. 342 bowl mill through a single burner. A ½ t. Raymond impact mill is also provided to supply either boiler for carrying Sunday load, and, the burners are so designed that oil firing for the same purpose may be added later. The large mills are each driven by 50 hp., 440 v. Westinghouse motors and the small mill by a 25 hp., 400 lb. pressure 1800 r.p.m. turbine. Steam pressure must be kept up 24 hr. a day, 7 days a week for fire protection purposes and to comply with insurance requirements. In addition, the boilers are equipped with Copes feedwater regulators, Edward blowoff valves, Bailey combustion control and instruments and a continuous blowdown system which dis-

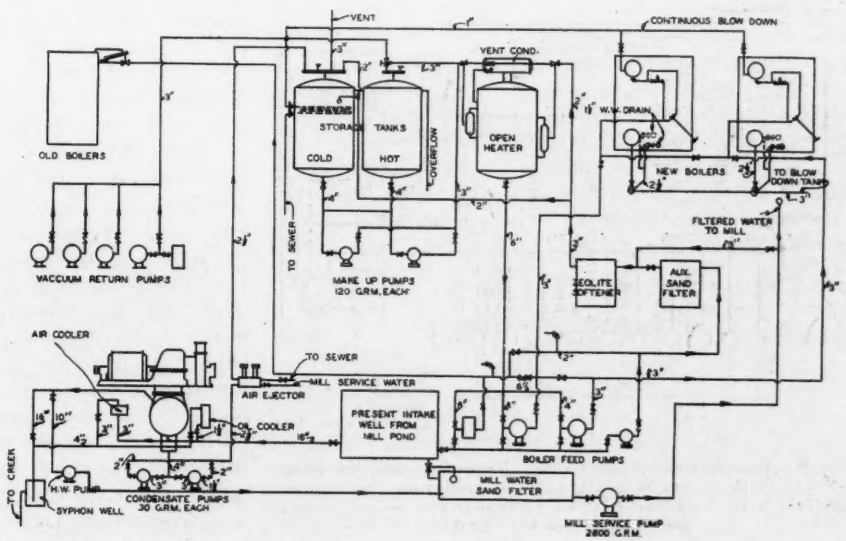


Fig. 6. Water piping diagram of the station. Feedwater makeup is normally taken from the mill supply system. The feedwater heater operates at 15 lb. ga. with extraction steam

charges to the sewer through heat exchanger coils in the cold water storage tank. All steam piping is Midwest Piping & Supply Co. with Crane valves.

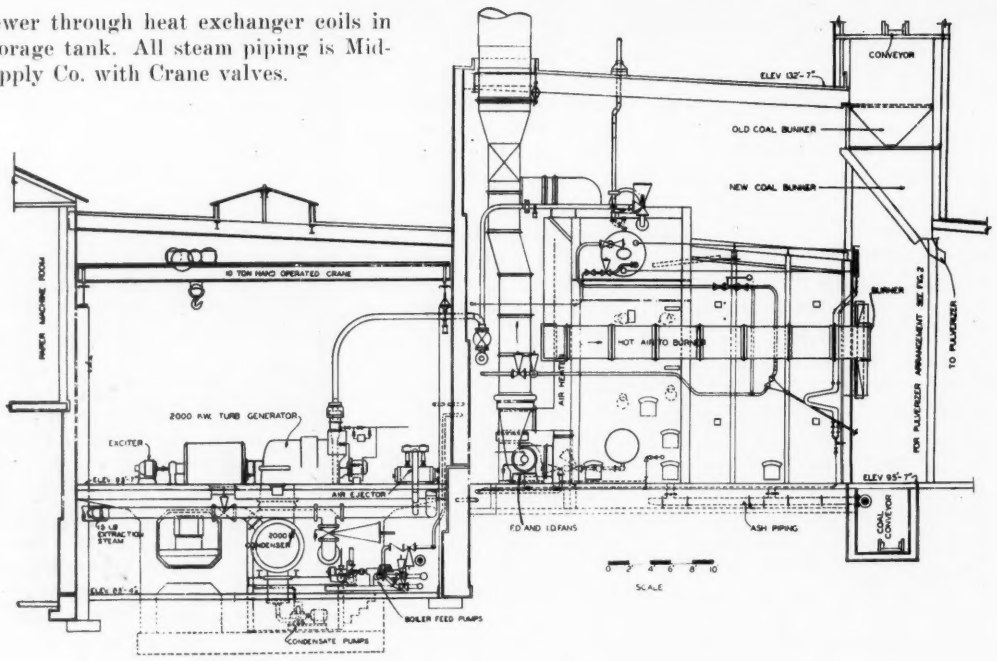


Fig. 7. Details of the equipment arrangement. Forced and induced draft fans, both driven by the same two speed motor, set back of the boilers on the ground floor. Boilers are equipped with air heaters and superheaters

Three boiler feed pumps, located in the basement adjacent to the turbines are provided; one of these, a simplex steam pump, remains from the old plant, retained for feeding the old 200 lb. boilers. The other two are new Worthington 3550 r.p.m. centrifugals designed for a capacity of 160 g.p.m. of 250 deg. F. water with a 15 lb. head on the suction and a 471 lb. discharge pressure. One is driven by a 75 hp. G. E. 440 v. motor, the other by a 70 hp. G. E. 400 lb. turbine. For taking care of the steam pump and other 150 lb. steam equipment from the new boiler in emergencies, the old and new steam systems are tied together with a Swartwout S-C 40,000 lb. per hr. reducing valve and desuperheater.

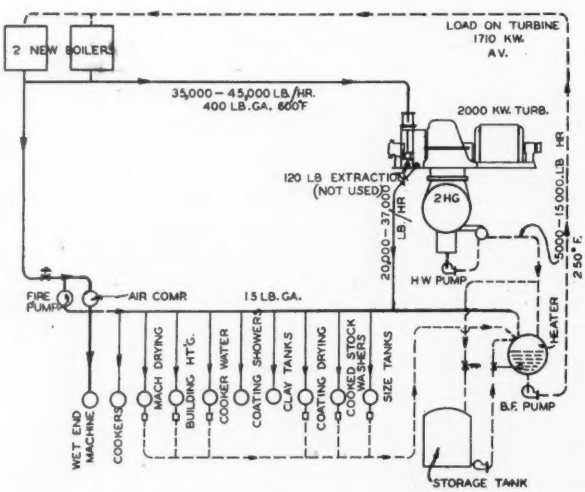


Fig. 8. Flow diagram of the station. Depending upon the season, 5000 to 15,000 lb. per hr. of steam will be condensed. In the winter the heat in the condenser water will be reclaimed in the mill water to provide complete heat recovery

Makeup for the boiler feed system, extremely important in a high pressure plant, is normally taken from the filtered mill supply through a Permutit Zeolite filter to two storage tanks with a total capacity of 12,000 gal. These in turn supply the two makeup pumps which discharge through a float controlled valve to a Cochrane 60,000 lb. per hr. deaerating heater. This heater, equipped with a vent condenser, is supplied with 15 lb. steam from the extraction loop and feedwater will be heated to 250 deg. F. In an emergency water may be pumped direct from the mill intake through a sand filter.

Makeup Small

Makeup requirements are, however, kept as small as possible and will not average over 20 per cent. Heating system, dryers and trap returns are collected and pumped back to a hot water storage tank and to avoid oil contamination and for other operating reasons, the old steam driven vacuum pumps have been replaced by Nash motor driven vacuum pumps. From the hot and cold water storage tanks the water is pumped to the open heater by two 120 g.p.m. makeup pumps.

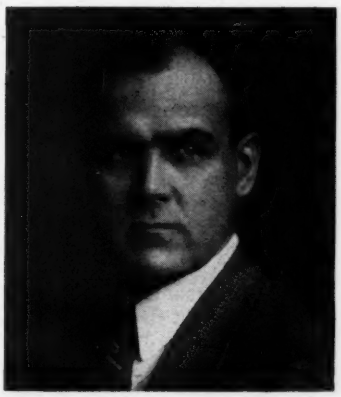
These tanks and the heater are located in the old auxiliary bay between the two remaining batteries of old boilers as shown on the plan, Fig. 3.

It is expected that the new plant will be in operation the latter part of March and the careful attention paid to heat balance and plant design should make it one of the most efficient in the industry. The engineering, design and construction was carried out by Sargent & Lundy, Inc., working with John Winterburn, Power Superintendent of the Allied Paper Mills. Miller-Davis Co. did the building construction. J. H. Busshouse is chief engineer of the Monarch power plant and Carl Ritter is in charge of the electrical construction work through the mill.

HEAT TRANSFER in Boiler Units

By treating heat absorption in boilers as a problem in heat transfer from gas to water the author has developed a graphical method of working out the response of tube banks and water walls to firing conditions.

By Loyd R. Stowe



Loyd R. Stowe's entire life has been devoted to a study of the many problems attending the generation of steam from the burning of coal. From thesis work on boiler tests at the University of Illinois he went to the Government fuel-testing plant. After more than two years of consantly conducting boiler tests with fuels from all the fields of America, he became interested in the boiler as an absorber of heat. This led to his being stationed, by the United States Government, at the University of Illinois, for the sole purpose of further analyzing all test data to see what this data would reveal concerning the subject of heat transfer in boilers.

When the City of Chicago made its first determined effort to rid its atmosphere of smoke, Mr. Stowe was selected to make a general survey of the industrial furnaces and boiler plants in order that he might assist in the formulation of ways and means of effecting improved combustion conditions.

For a number of years he was engaged in selling stokers, air-cooled walls and arches through the Mississippi valley, which led to the development of the Stowe stoker for central stations and the larger industrial plants.

As chairman of the Stoker Manufacturer's Committee for Revising the A. S. M. E. Rules for Conducting Boiler Tests, he contributed many refinements to the present Code.

He has for some months now been engaged in sales and engineering work in the Chicago territory for the Titusville Iron Works Co.

FOR RESEARCH in heat transfer in boiler, the most practical information comes from data secured in the boiler room. For a proper interpretation of this data, a good background in combustion engineering is helpful.

I have made some discoveries in these branches of engineering that enable me to reduce the problems of heat transfer in boilers to what I consider a very exact science, and to express this science in easily understandable language.

Any engineer who will deal with a few, simple quantities, and who has a fund of well-selected, boiler-test data, can now work out any problem in heat transfer in boilers and related equipment.

Suppose we have a simple, cubical, fire-brick enclosure, or furnace, that is provided with a smoke outlet and a roomy flue therefrom. There are no boiler surfaces of any kind in this furnace and flue, but there is some definite way of generating heat in this furnace; for example, the employment of a stoker.

Through the use of this stoker, let us develop, or release in this furnace 100,000,000 B.t.u. per hour. We can release this definite quantity of heat by burning the fuel with the minimum amount of air, in which case we say we have high furnace temperatures and high CO_2, or we can release this definite amount of heat with a great excess of air with resulting low temperatures and low CO_2.

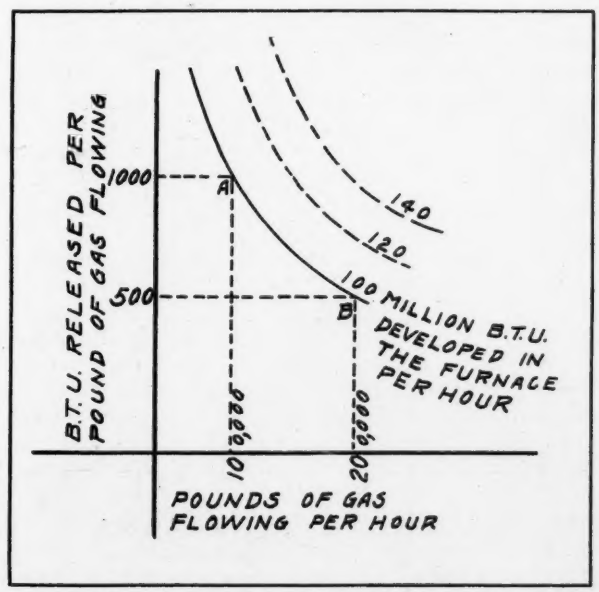


Fig. 1. Heat developed, heat released and gas flow relationship

In the first instance, there is considerable B.t.u. released per pound of gas, perhaps 1000. In the second case, there is a low heat release per pound of gas, perhaps 500. The difference is in the quantities of gas involved, for the total heat released remains constant here at 100,000,000 B.t.u. per hour. We can graphically show these conditions on Fig. 1.

Influence of Temperature

The furnace temperatures, of course, will be higher at "A" than at "B" because of the greater amount of heat carried by each pound of gas. We all agree that the conditions of heat development represented by point "A" are more favorable to efficient heat transfer than the conditions indicated by point "B." Hence, all investigators of this general subject have put forward

the matter of temperature as their most important factor.

I want you to put aside the idea of "temperature" entirely in order that we may bring boldly to the foreground the more important factor in heat transfer, namely—quantity of heat developed per square foot of surface under observation.

To illustrate my point, let me ask, "How much power can be developed from a water fall one hundred feet high?" Such a head is extremely favorable to power generation, but if there isn't much water available, there isn't much power developed even though the potential is high. Similarly, the opportunities of transferring heat lie primarily in the quantity of heat available. We can transfer great quantities of heat per square foot of boiler surface per hour at low temperatures if we have great quantities of low head heat to transfer, but we can't transfer very much heat at high temperature if we don't have the heat available to start with. One doesn't have to be a scientist to grasp these simple facts, and when we begin to talk in terms of "heat quantities," we are far along the road leading to a clear understanding of the science of heat transfer in boilers and parts thereof.

In the matter of "heat generation," let us confine ourselves to heat released in the furnace per hour. We can divide this total quantity of heat either by the total pounds of gas flowing per hour, or by the total amount of boiler surface under observation, using that quotient which best suits our particular needs.

In the matter of "heat absorption," we shall conform to the long-established practice of expressing heat absorbed in B.t.u. absorbed per hour per square foot of surface under consideration.

Referring to Fig. 1, if the heat released per hour were increased to 120,000,000 B.t.u. and then to 140,000,000 B.t.u. per hour, we would have additional curves on this chart which are shown dotted. As yet, this Fig. 1 reveals nothing relating to heat absorption. It just shows the various ways in which definite quantities of heat can be developed per hour.

Boiler Surface

Now, let us bring some boiler surfaces into the picture. Let us line the furnace with 1000 sq. ft. of water walls that will pick up heat radiated from the furnace even though the gases do not touch the water walls; and in the smoke flue outside the furnace, let us place 9000 sq. ft. of tube surface. The gas will have to scrub or contact these latter tubes in order that the gas can give up its principal remaining heat. Let us suppose, for the moment, that this combined 10,000 sq. ft. of surface of water wall and tube bank picks up *all* of the furnace heat; the water wall by radiation, the tube bank by contact. In other words, suppose we had an absorption efficiency of 100 per cent. Then, Fig. 1 would not only be a chart of firing conditions, but it would also immediately become a definite characteristic of the boiler as a heat absorber under all firing conditions. That is,

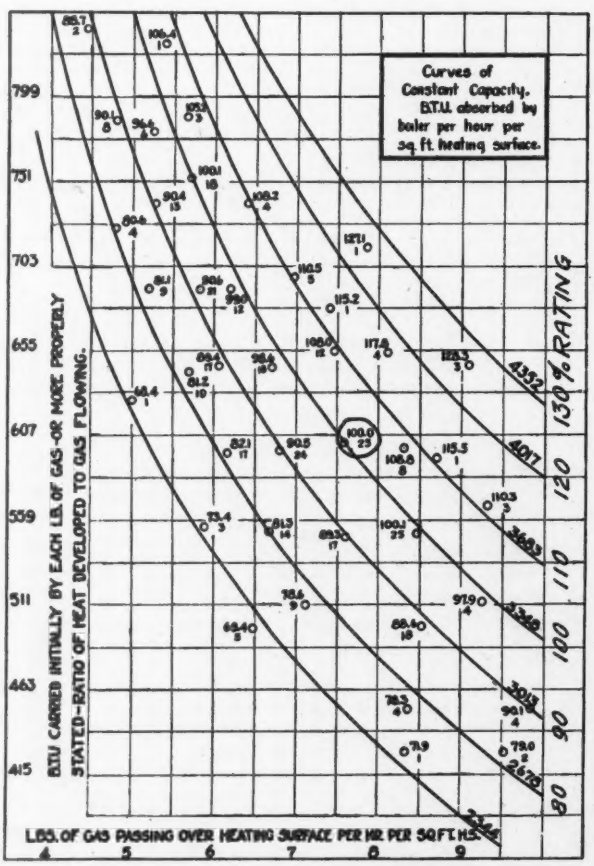


Fig. 2. Heat absorption curves plotted from boiler test

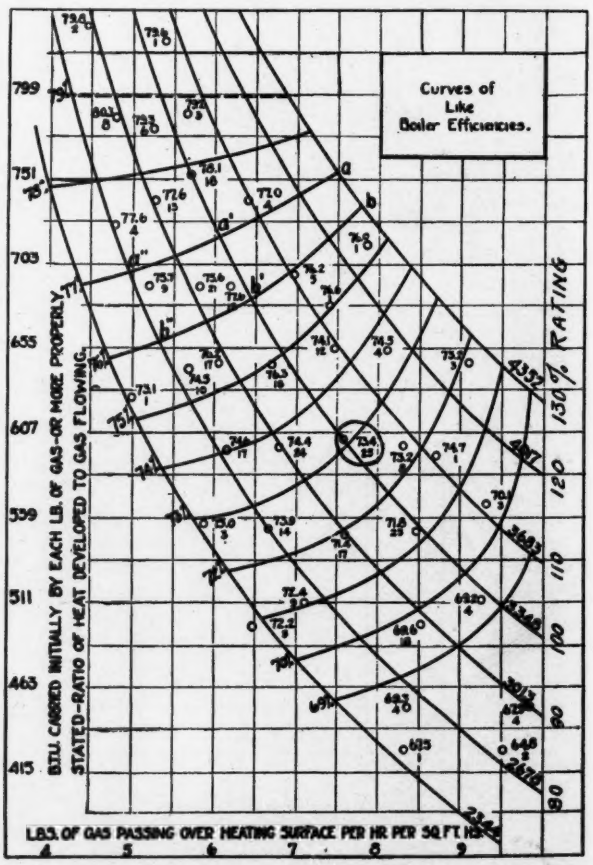


Fig. 3. Chart showing curves of like boiler efficiencies upon which are located results of boiler tests

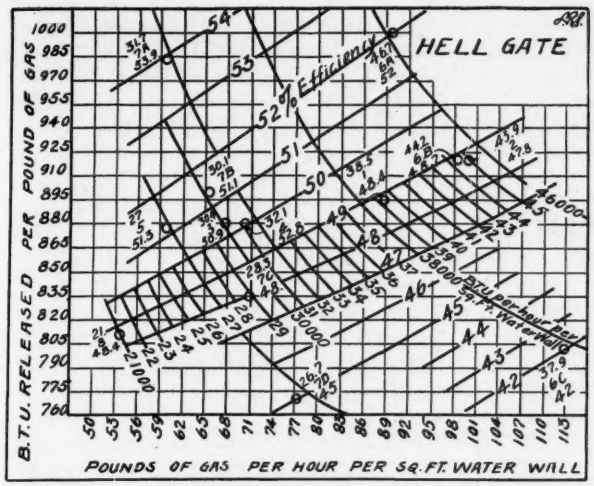


Fig. 4. Water wall absorption test results plotted for comparison with curves

with 1000 B.t.u. released per pound of gas and 100,000 lb. of gas flowing per hour, there would be 100 million B.t.u. absorbed or 10,000 B.t.u. absorbed per sq. ft. of boiler per hour.

These curves, however, are curves of constant absorption with 100 per cent efficiency. Of course, the absorption efficiency is not quite 100 per cent. Therefore, as we begin to encounter conditions of less than 100 per cent absorption efficiency, 99-98-97, etc., these curves of constant "absorption" will begin to depart from the curves of constant "heat release." At the upper end of the chart, with high CO_2 they will not depart so much because the absorption efficiency is high, but with lower CO_2 they will drop away considerably.

Figure 2 is such a set of heat-absorption curves of an actual boiler from actual boiler-room data, but with the lines of constant "heat development" omitted from the chart.

An explanation of the heavily-encircled point near the center of the figure will furnish the key to much of the information which this chart reveals. The "25" indicates that 25 tests were averaged to secure the data for the location of this point. The average B.t.u. released per pound of gas flowing was 602. The gas flowing per square foot of boiler surface was 7.6 lb. Under these conditions of combustion each square foot of boiler surface absorbed 3348 B.t.u. per hour. (See numbers at lower end of curve.) This was equivalent to 100 per cent builder's rated capacity of the boiler. (Note the 100 adjacent the point.) Please note the precision with which all the points fall in regard to the evenly-spaced, smooth curves. This precision indicates that we have discovered the conditions that definitely determine the exact amount of heat absorbed.

Absorption Efficiency

Since the product of the coördinates represents heat developed, and these curves now show heat absorbed, we can easily determine the absorption efficiency for each point on these curves and establish lines of constant efficiency. Figure 3 is such a chart. The entire surface of the boiler is under observation in these Figs. 2 and 3. The heavy circle around the central point of Fig. 3 now contains the number of tests averaged for this point and also the average absorption efficiency of these tests. Here again, note the precision with which the average efficiencies fall with regard to the lines of uniform efficiencies.

In Fig. 3, the top part represents hot furnace conditions, and a considerable part of the heat was absorbed by radiation from fuel bed and flame. For the condition represented by the lower part of this figure, the absorption was almost entirely through the agency of the scrubbing of the gases along tubes, i.e., contact. This statement will give the super-technical theorist somewhat of a shock; that the absorption results from radiant energy and absorption results from contact can all be plotted on one chart. The explanation is simple. Absorption by radiation follows one set of laws and pro-

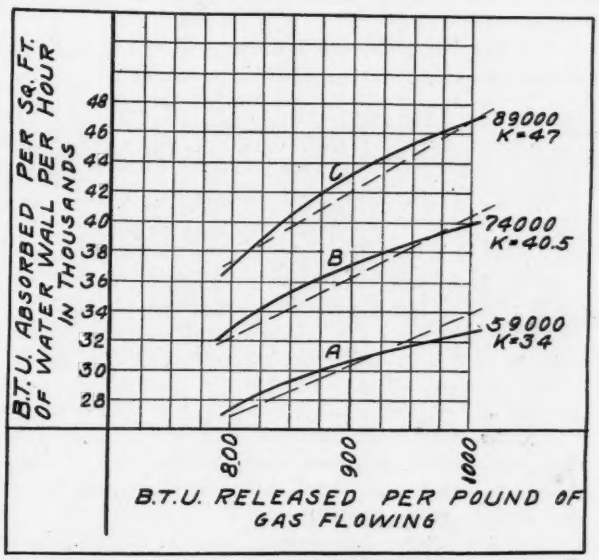


Fig. 5. Heat absorption of water walls in Hell Gate boiler

duces a definite form of characteristic. Absorption by contact follows an entirely different set of laws, and results in its own distinct form of chart. Both of these differing characteristics, however, can be plotted on the same coördinate axes. Therefore, the sum of these two differing influences can also be plotted on this same set of coördinates.

Water Walls

Now, let us take just a part of a boiler—the water walls with their heat transfer by radiation alone. Fig. 4 is the result showing the characteristics of the water walls of one of the boilers of the New York Hell Gate Station. I have developed this figure from data secured by De Baufre.

The numbers adjacent the plotted points show, in the order named, the B.t.u. absorbed per hour per square foot of water wall in thousands of B.t.u.; Mr. De Baufre's test number; and the per cent of total heat developed that was absorbed by the water walls. Fig. 4. in general makeup, is similar to Fig. 3.

Here again, in Fig. 4, note with what precision the points, plotted from observed data, conform to the evenly-spaced, smooth curves of constant heat absorption and constant absorption efficiency.

These simple charts are so fundamental and yet so

complete that I have been able to expand the information which they may be made to reveal into a complete science from which every practical question in the design of steam-generating equipment, from a heat-transfer viewpoint, can be answered.

At the beginning of this paper, stress was laid on the importance of taking recognition of the quantity of heat available. Let us refer to Fig. 4, and note some particular value of the B.t.u. released per pound of gas flowing; for example, ordinate 895. This definite amount of heat released per pound of gas is at least one conception we may have of an initial temperature condition applying to all tests on the horizontal 895 line. With this fixed temperature condition, the rate of absorption increases from 27,000 B.t.u. per hour per square foot of wall to 46,000 B.t.u. simply by presenting more heat to these walls.

The Stephan-Boltzman law states that the amount of heat radiated from a surface is proportionate to the fourth power of the absolute temperature. This law can not well be applied to the intricate, involved and complex conditions within the four walls of a boiler furnace.

We can, however, look for the influence of B.t.u. released per pound of gas flowing by keeping constant the total pounds of gas flowing per hour, or keeping constant the total amount of heat released in the furnace per hour. This latter condition seems more plausible.

Figure 5 reveals the heat absorption of the water walls at Hell Gate under three conditions. The lower curve "A" shows the conditions of absorption when the heat development is kept constant at 59,000 B.t.u. per hr. per sq. ft. of wall surface. Curves "B" and "C" show absorption conditions when the heat release is increased to 74,000 and 89,000 B.t.u. per hr. per sq. ft. of wall surface, respectively.

It will be noted that, within limits of the test data shown on this chart, these curves can be approximated by straight lines (shown dotted). This is in contrast to any fourth-degree equation. This straight-line approximation is another way of saying that, within the range of our test data and with the rate of heat development fixed, the B.t.u. absorbed is practically a product of some constant "K" (shown at the right of each curve) and the B.t.u. released per pound of gas flowing.

These charts are simpler and more direct than formulas of any kind. They are an exact portrait of the heat-absorbing characteristics of a surface and, formed as they are of actual data, give a marked finality to the conclusions based on their proper use.

Stoker Regulation

By A. BEMENT

IT IS natural to assume that stokers as erected are in condition to function in an economical and satisfactory manner. This, however, is not always true usually they require considerable experimenting before the most satisfactory operating conditions are determined. Many chain grates are deficient in provision for the regulation of speed. Often it is impossible to get the chain to run slow enough to make it possible to obtain a satisfactory performance, the result being that the tendency is for the fire to run too long, with the result that it spills off the end of the chain. This causes a loss of fuel in the ashes and refuse. The proper remedy would, of course, be to slow down the speed, but as this is not possible, two choices are available. One is to reduce the thickness of the fuel bed so that the coal will burn out by the time the fire reaches the end of the grate. This condition results in inferior combustion and reduced capacity. The other alternative is to carry a fire thickness that will give the capacity necessary to carry the load on the boiler and let the fire run over the end of the stoker, either of which results in low efficiency of combustion or, on the other hand, loss of fuel in the refuse.

The inability to drive the stoker fast enough need not give as much trouble as failure to run slow, because this condition may be compensated for by increased fire thickness.

Proper thickness of fire is a very important feature. It depends on strength of draft, load to be carried by the boiler, size of the coal, and ability to obtain ignition of the coal as it passes to the grate.

Failure to obtain proper ignition is due either to thin fire or oversized coal. The remedy for each is an increase in thickness of fire.

The best results may be had when a thick rather than a thin fire is carried, provided the stoker can be driven slow enough. If it cannot be so driven, the equipment should be changed so as to remedy the situation.

Underfeed Stoker

With the single retort underfeed stoker, which is used so extensively in small and medium sized boiler plants, forced draft air pressure is a feature of special significance. Too often these stokers are not provided with an air pressure gage showing the strength of the forced draft, and this may be the cause of difficulties experienced, because the operator may not know what air pressure prevails. The result is that more often an excessive pressure is carried. The result is to burn coal in proportion to air pressure, with the tendency for excessive steam production. If, under such conditions, coal supply be reduced as a remedy for excessive steam production, efficiency of combustion drops due to excess air supply.

The desirable air pressure is the lowest that will carry the load on the boiler. This may range from one-quarter to one-half inch of air pressure. With extreme heavy load, a pressure of from one to 2 in. of water may be necessary.

While air pressure may and should vary with the load on the boiler, the quantity of fire in the furnace should be at maximum at all times. The rate of feed of coal, however, must be in proportion to air pressure.

In the absence of a knowledge of the air pressure, excessive pressures may be carried, with the result that too much steam may be produced, and if under this condition coal feed be reduced to hold steam production, it follows that efficiency of combustion declines due to excess air.

Present Status of STEAM TURBINES

Technical advances and changing plant trends have made possible a degree of standardization not heretofore possible in the central station industry

By E. R. Kauffman,
Turbine Division, Westinghouse Elec. & Mfg. Co.

RECENT INCREASED ACTIVITY in the construction of turbines for the central station industry indicates, for the first time in five years, a definite trend in the type of unit and operating conditions which best fulfill its requirements. In any consideration of this subject, it should be kept in mind that the economic conditions and load requirements are the major factors governing such a trend. Fixed charges rather than operating charges have, during the past few years, been the principal object of scrutiny and the relatively greater importance of the former is clearly reflected in the types of turbine now under construction.

Turbines for which designs have been developed, and which it is believed will fulfill all requirements of the present and near future, may be divided into the following types (listed in order of their importance at the present time):

1. 3600 r.p.m., non-condensing, superposed units for ratings up to 62,500 kw.
2. 3600 r.p.m., single cylinder, condensing units for ratings up to 20,000 kw.
3. 3600 r.p.m., two cylinder tandem condensing units for ratings of 20,000 to 40,000 kw.
4. 1800 r.p.m., single cylinder, condensing units for ratings of 25,000 to 100,000 kw.
5. 1800 r.p.m., two cylinder tandem, condensing units for ratings of 100,000 to 200,000 kw.

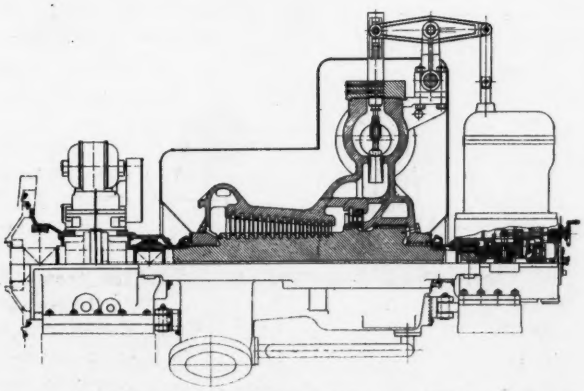


Fig. 1. West End turbine, a 35,000 kw., 3600 r.p.m., 1200 lb., 900 deg. F. superposed unit for 260 lb. ga. back pressure

The more important units now under construction are designed for inlet temperatures of 900 to 950 deg. F. It is believed advisable to limit this temperature to 950 deg. F. maximum, including swings, until some practical operating experience is obtained before going further. By using inlet temperatures of this order in condensing cycles and limiting the moisture content in the exhaust to 12 per cent, these turbines can utilize economically pressures up to 1200 lb. per sq. in. ga. without reheating.

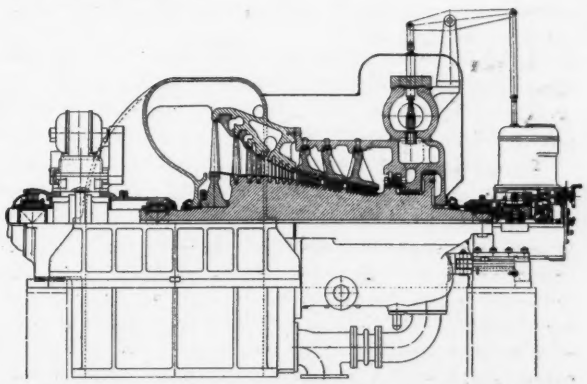


Fig. 2. Montville Station will have the largest single cylinder 3600 r.p.m. condensing turbine, a 25,000 kw. unit operating at 640 lb. ga., 825 deg. F.

These high inlet steam conditions are being adopted rapidly by the industry and a large proportion of the units ordered during the year are for conditions closely approaching these limits. The advantages are of outstanding significance in that they permit the use of higher rotative speeds and relatively smaller parts with an increase in sturdiness of construction. These are exemplified by the great increase in capacity of the 3600 r.p.m. machines, particularly in the superposition field.

The superposition principle[1] seems to be the only method whereby technical advances in steam engineering can be applied to existing stations without excessive capital investment.

Superposed turbines can be operated with either varying or constant exhaust pressure. If the lower pressure turbines are segregated from other sources of

[1]See The Superposition Power Plant, by Norris D. Gove, p. 512, Power Plant Engineering, September 1936.

steam supply, the machines involved form a compound unit and the exhaust pressure of the superposed element varies according to the load carried. This is the most efficient arrangement. In such a case, the high pressure governor controls the entire compound unit and the governors on the low pressure machines are set slightly above normal full speed and function only in case of overspeed. The other arrangement in which the superposed turbine exhausts into a lower pressure boiler header necessitates operating against a constant exhaust pressure. The load on each unit is then controlled by the individual speed changers. An exhaust pressure regulator maintains full load on the high pressure turbine as long as the pressure in the exhaust header does not exceed normal, but reduces the load if this pressure does exceed normal. The present trend seems to favor the constant exhaust pressure form of operation.

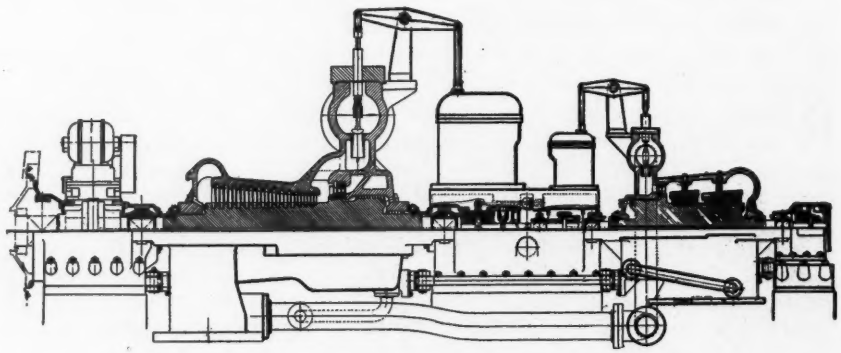


Fig. 3. Waterside turbine, a 50,000 kw., 3600 r.p.m., 1200 lb., 900 deg. F. superposed unit operating at 200 lb. ga. back pressure and incorporating a special feed heating turbine on the main shaft. This turbine takes steam at 200 lb. ga., 502 degrees F., bleeds at 60 lb. ga. and exhaust at 5 lb. ga. It is equipped with a back pressure governor

Figure 1 shows a longitudinal section of a 35,000 kw. turbine of this type for the West End Station[2]. It is designed for 3600 r.p.m., and steam conditions of 1200 lb. ga., 900 deg. F. and 260 lb. back pressure. Figure 3 shows a similar view of the 50,000 kw. superposed turbine for Waterside Station. It is designed for 3600 r.p.m. and steam conditions of 1200 lb. ga., 900 deg. F., 200 lb. back pressure. The outstanding feature of the second machine is a feed heating turbine[3], connected in tandem to the main unit, and arranged to receive steam at the main exhaust pressure and bleed into 60 and 5 lb. ga. heaters. The main inlet valves are responsive to either speed or main exhaust pressure, while the inlet valves of the feed heating turbine are controlled by the 5 lb. exhaust pressure.

This arrangement is indeed an important innovation in power plant engineering. One problem encountered in a superposed application is that of heating the feedwater to the economical point for the increased inlet steam conditions. Many of the older machines for which superposition is desirable do not have suitable openings for extraction of steam for feed heating. To provide such openings involves extensive rebuilding of the older machines at excessive costs, and in some cases such changes are impossible. The feed heating turbine solves this problem, giving the desired heat balance in a most practical manner.

[2]See New 35,000 kw. Top Unit For West End, Cincinnati, O., by D. S. Brown, p. 446, Power Plant Engineering, August 1936.
[3]See Integral Feed Heating Turbine, by W. E. Caldwell, p. 636, Power Plant Engineering, November 1936.

Limiting Factors

Capacity limit of the superposed unit has been given above as 62,500 kw. The actual limiting factor is probably the maximum steam flow that can be handled with practical forms of inlet arrangements. A tentative limit of about 2,000,000 lb. per hr. is believed reasonable. With the steam conditions now in vogue, these steam flows will easily develop capacities greater than 62,500 kw. It would seem inadvisable to push this limit much further in view of the enormous steam capacity which is dependent upon the reliability of a single unit.

Most notable advances in the size of individual units have been made in the 3600 r.p.m. class, which is particularly important in view of its adaptability to high inlet temperatures. Up to last year, 10,000 kw. was the largest single cylinder, condensing machine built to operate at 3600 r.p.m. and 15,000 kw. was the largest in the two cylinder tandem arrangement.

This limit has been more than doubled by a 25,000 kw., 3600 r.p.m., single cylinder condensing unit for Montville Station. The steam conditions are 640 lb. ga., 825 deg. F. and 29 in. vacuum. Figure 3 shows the general features of design. This is the first unit to be built of a new 3600 r.p.m. condensing line and is the largest of its type contemplated at the present time. A similar line of two cylinder tandem, condensing machines has been developed for ratings of 20,000 to 40,000 kw. Figure 4 shows the construction features of this arrangement.

Naturally, there is still a large field of plant extension in which the 1800 r.p.m. machines will always retain their importance. Single cylinder units for opera-

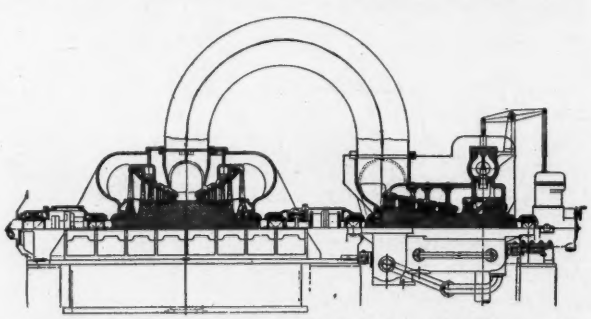


Fig. 4. Two cylinder condensing tandem turbines of this type may be built for a speed of 3600 r.p.m. in sizes up to 40,000 kw. For 1800 r.p.m. tandem compound turbines may run up to 200,000 kw.

tion at this speed can now be built for capacities up to about 100,000 kw. Two cylinder, tandem construction permits roughly twice this capacity or 200,000 kw.

These units, likewise, comprise a new line which has been developed during the past few years. Notable changes include those necessitated by the higher inlet steam temperatures and numerous mechanical details of recent design which have been standardized for all types of central station machines. In general, the construction of these 1800 r.p.m. machines follows closely that shown in Figs. 2 and 4 for the 3600 r.p.m. line.

Many Developments Aid Advance

The new types of construction and advances involve many problems and the results thus far accomplished

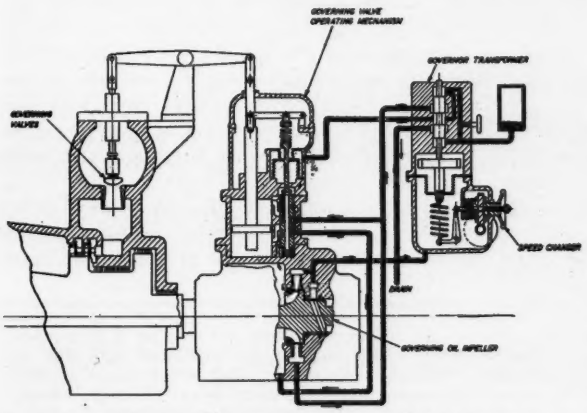


Fig. 5. Type of pressure-transformer governor used by Westinghouse on all units of 10,000 kw. and over

would have been impossible without the great amount of research and special development work carried out by design engineers and metallurgists. Of these problems, those surrounding the advance in inlet steam temperature are the most difficult and of greatest significance.

In addition to the studies of creep characteristics and their influence on turbine design[4], a great amount of development work in other lines has culminated in improved mechanical details which are certain to give better operation and greater reliability. These improvements are being incorporated in practically all new units now under construction by the Westinghouse Co. for central station service.

Important prerequisites in cylinder design are uniform heating of the machine when the first valve is opened and freedom from pipe strains and distortions which may retard expansion and contraction and a minimum of extrapped steam between the control valves and the nozzles. This last requirement has become more important than ever because of the high torque and low rotary inertia of the relatively small 3600 r.p.m. superposed turbines.

The first condition is met by providing a steam belt extending around the entire cylinder at the inlet end. This chamber serves as the steam passage between the No. 1 governing valve, located in the cover, and its nozzles which are located in the base. It, therefore, is filled with high temperature steam as soon as the first valve opens and maintains equal temperatures in the base and cover.

Pipe strains are reduced to a minimum by casting the steam chest integrally with the cylinder cover. The valves are operated by a bar-lift mechanism similar to the type which has been used on smaller machines for a number of years. The inlet end cylinder support has been altered to insure a greater freedom of expansion. The cylinder is still supported by arms resting on a separate pedestal as in former designs, but the arms now serve only as supports and axial movement of the cylinder is transmitted to the pedestal by a pin joint and draw bar placed so that the force is exerted in the plane of sliding.

Blading

Entrapped steam is, of course, reduced to a minimum by the integral steam chest construction. In rotor design, joints are avoided wherever possible. All of the high temperature machines have solid rotors. In condensing units, discs are shrunk on the rotor body to carry a part of the low pressure blading.

Latest practice in the mechanical construction of blading includes the use of shrouded blades throughout the machine. With this construction, the use of silver soldered lashing wires practically disappears. In the last two or three rows where lashing is still necessary, streamlined lashing welded to the blades is the standard practice. The use of stellite shields welded to the inlet edges of the blades continues to be the most satisfactory method of reducing erosion of the low pressure blades. This construction is used wherever such protection is required.

Governor

A new type of hydraulic governor, known as the pressure transformer type, has been embodied into a standard device and is being applied to all turbines of 10,000 kw. and above. It consists of three principal parts, namely, a reverse flow impeller attached to the turbine shaft, a pressure transformer and a servo-motor for operating the governing valves. Figure 5 shows a diagram of this mechanism in its simplest form. The impeller, being mounted on the turbine shaft, delivers a pressure which varies as the square of the turbine speed. Hence changes in this discharge pressure are an accurate measure of changes in rotative speed and provide the governing impulses to the pressure transformer.

The transformer multiplies these pressure changes so that the total change in fluid pressure available for operation of the servo-motor relay is relatively large, and unavoidable friction of relays, etc., is of correspondingly little significance. An ample supply of high pressure oil delivered by the main oil pump serves as the motive power in the servo-motor.

Unlike former impeller type governors, there is no actual flow in the discharge from this reverse flow impeller. Hence it is not affected by variations in oil demand and the pressure maintained follows speed changes with a high degree of accuracy. The entire mechanism provides a control which is sensitive, powerful and reliable.

[4]For Mr. Kauffman's summary of advances in Metallurgy, creep characteristics and influences on turbine design see p. 39 of the January 1937 issue of Power Plant Engineering.

THE STEAMOTIVE

By E. G. Bailey, The Babcock & Wilcox Co.; A. R. Smith, General Electric Co., and P. S. Dickey, Bailey Meter Co.

STUDIES MADE some few years ago indicated that there should be a good field of application for small steam-generating units of good efficiency, relatively light weight, and small space requirements, in the field of power-generating equipment for installations of small and moderate capacity, say from 1000 hp. to 10,000 hp. In order to compete with other prime movers in this field the steam should be generated at as high pressure and temperature as appears feasible; and in order to reduce the operating expense it was agreed that fully automatic control of the steam generation in response to changes in demand would be a very desirable feature.

Objects to be attained in the construction of this complete portable steam power plant were: High steam pressure and temperature; minimum weight and size per unit of steam produced; wide range of capacity with ability of the unit to respond quickly to wide variations in load conditions; adaptability to wide range of fuels; completely coördinated auxiliaries; completely coördinated automatic control; units to be of simple design and to be constructed in sizes small enough to be portable.

Following preliminary work, a developmental steam-generating unit was built and put in operation to perfect the design of the various component parts under actual operating conditions. This complete steam-generating unit was called "steamotive." It was oil-fired and designed for an output of 21,000 lb. of steam per hr. at a pressure of 1500 lb. and a temperature of 1050 degrees F. leaving the superheater, later changed to 900 deg. F. Auxiliaries, geared together as one turbine-driven unit, consisted of a feed pump which delivered 25,000 lb. of water per hr. at a pressure of 2000 lb.; a blower for 30,000 lb. air per hr. at 60 in. water pressure; a fuel-oil pump; and a lubricating oil-pump, meters and complete automatic control, coördinate the auxiliaries and the supply of fuel, air, and feedwater to control steam output, pressure, and temperature, together with complete automatic ignition and safety equipment.

No serious defects were encountered in any of this equipment. During tests the complete unit operated 950 hr., much of which time was at continued maximum rating with long periods under extremely variable load conditions, such as would be encountered in regular locomotive road service. The combustion of oil exceeded 400,000 B.t.u. per cu. ft. per hr. on peaks and 375,000 under continuous load. The unit operated over a range of output of 10 to 1 under complete automatic control. This unit is now in commercial service in the Lynn Works of the General Electric Co.

Occasionally something so new and startling is developed that the public finds it difficult to comprehend until after a lengthy period of readjustment. This was the case of the Steamotive, announced last December before the annual meeting of the A.S.M.E. by the above authors in a paper of which this is an abstract.

Although rumors of the development broke forth from time to time, the work was carried on and the tests made in comparative secrecy and took the engineering profession completely by surprise.

It is easy to look back over a period of years to the locomobile, the series boiler, higher pressures and temperatures and metallurgical programs and show that this is a very logical development to meet the needs of the modern railroad. Nevertheless it is an outstanding piece of work by the three companies involved, the Babcock & Wilcox Co., General Electric Co. and Bailey Meter Co. and is but a forecast of what cooperative effort by progressive concerns can accomplish. Although developed for comparatively small steam outputs at present it is perhaps indicative of future furnace construction for larger boilers; all metal furnaces, positive furnace pressures and completely coordinated auxiliaries.

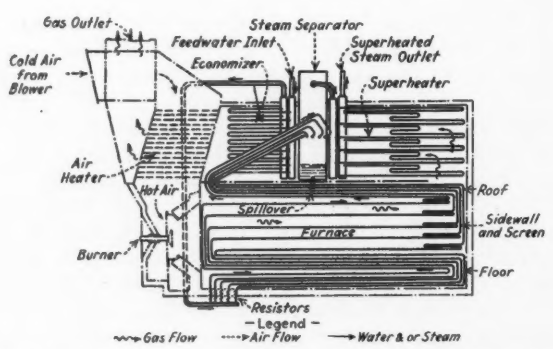


Fig. 1. Flow diagram of the experimental unit which is horizontally fired

A complete turbine-generator plant using one oil-fired Steamotive unit has been built for a large industrial concern and is now being installed in one of its small isolated manufacturing plants for supplying electric power and low-pressure steam for building heating. This unit has a capacity of 10,000 lb. per hr. and furnishes steam to the turbine at 1200 lb. per sq. in. and 950 deg. F.

Two oil-fired units, each having a capacity of 40,000 lb. per hr. are now being constructed for the Union

Pacific Railroad for driving two 2500-hp. electric locomotives. These units will furnish steam to the turbines at 1500 lb. per sq. in. and 950 deg. F.

Installation of Developmental Steamotive Unit

The first developmental Steamotive unit was assembled at the Schenectady Works of the General Electric Co. for test.

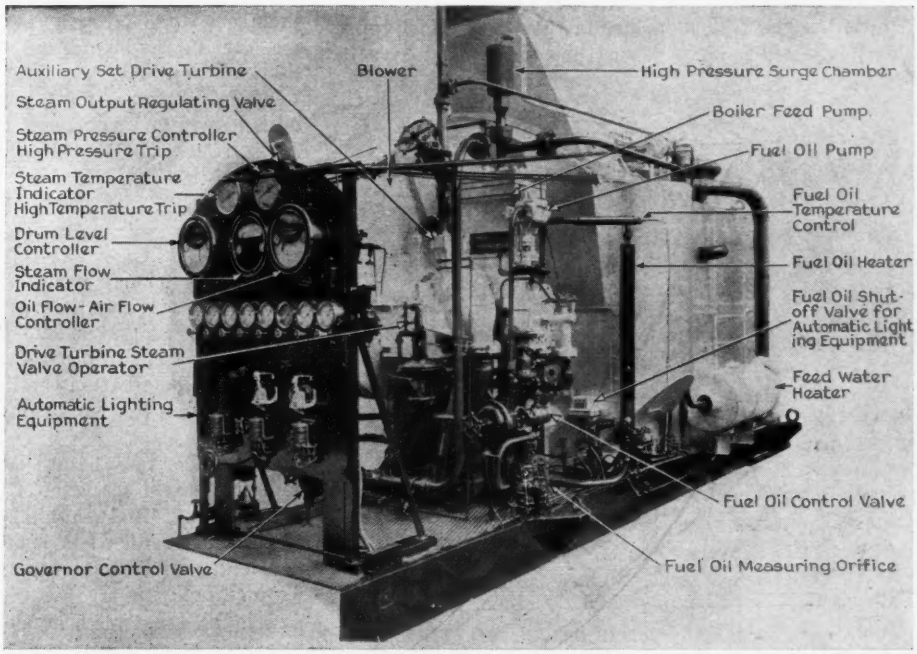

Auxiliary Set Drive Turbine
Steam Output Regulating Valve
Steam Pressure Controller High Pressure Trip
Steam Temperature Indicator High Temperature Trip
Drum Level Controller
Steam Flow Indicator
Oil Flow - Air Flow Controller
Drive Turbine Steam Valve Operator
Automatic Lighting Equipment
Governor Control Valve
Blower
High Pressure Surge Chamber
Boiler Feed Pump
Fuel Oil Pump
Fuel Oil Temperature Control
Fuel Oil Heater
Fuel Oil Shut-off Valve for Automatic Lighting Equipment
Feed Water Heater
Fuel Oil Control Valve
Fuel Oil Measuring Orifice

Fig. 2. General arrangement of equipment on the experimental unit as installed at Lynn. All auxiliaries are driven by a single turbine

The flow diagram of the unit is shown in Fig. 1, and the general appearance and arrangement of equipment constituting the Steamotive unit in its final condition during the later stages of test at Schenectady and as operating at the Lynn Works of the General Electric Co. today is shown in Fig. 2.

From the burner the flame and gases pass horizontally through the completely water-cooled furnace, thence up and back with a 180-deg. turn into the superheater, flowing around the separator, through the economizer and air heater and up the stack. The air for combustion leaves the blower at relatively high pressure, passing through lanes intersecting the stack and down around the air-heater tubes to the oil burner. There is no induced-draft fan, the blower forcing the air through the burner and furnace under pressure.

Boiler heating surfaces is as follows:

Furnace projected surface, sq. ft	112.3
Boiler-screen convection surface, sq. ft	115.9
Superheater projected radiant surface, sq. ft	30.5
Superheater convection surface, sq. ft	127.8
Economizer, sq. ft	275
Air heater, sq. ft	578

Feedwater enters the economizer inlet header, and, after leaving the outlet header, is divided into five circuits, all five of which form the floor, sides, and roof of the furnace as well as the two sets of loops forming the boiler screen. All the steam is generated in these five furnace and boiler circuits and enters the separator with a surplus of about 400 lb. of water per hr. in each circuit. From the separator the dry steam goes through the superheater and directly to the main turbine. The water from the separator is called the "spillover," and it passes through a heat exchanger to the hot well where it mixes with the condensate and is re-fed to the boiler by the feed pump.

Desired rate of water flow is established by measured indications of total boiler steam flow and separator-drum level, and the variable water-flow governor regulates the speed of the turbine driving the auxiliary set to maintain this water flow regardless of variations in steam or water pressure, feed-pump efficiency or other variables.

Burner is provided with a propane torch with dual spark ignition and with a photoelectric flame indicator. A three-way valve is provided in the oil line to the burner to shut off automatically the fuel-oil supply to the burner and recirculate the oil to the suction side of the oil pump. This three-way valve, the solenoid valve in the propane line to the torch, and the spark igniters for the torch are interlocked to perform the following functions:

1. Upon closure of the lighting switch, the igniters are energized and the propane valve opens, lighting the torch. After a short delay, the fuel-oil control valve is opened to the burner, and as soon as ignition of the oil fire is established, as indicated by the photoelectric flame detector, the propane torch and igniters are cut off after a short time delay.

2. The fuel oil is shut off in case of:

a, High boiler pressure; b, high superheat temperature; c, high temperature at outlet of any furnace circuit; d, flame failure.

3. The oil burner is automatically relighted as in Par. 1 when 2a, 2b, and 2c are restored to normal.

4. Upon loss of flame only, the relighting cycle is repeated several times, and if flame cannot be established, the unit is shut down, requiring manual reset.

5. Upon loss of feed-pump suction pressure or loss of auxiliary-set lubricating-oil pressure, the oil fire and torch are cut off and the air supply to the governor of the auxiliary-set turbine is likewise cut off, shutting down the auxiliary set.

Test Results

Before the tests were begun there was some apprehension about being able to reach the desired capacity

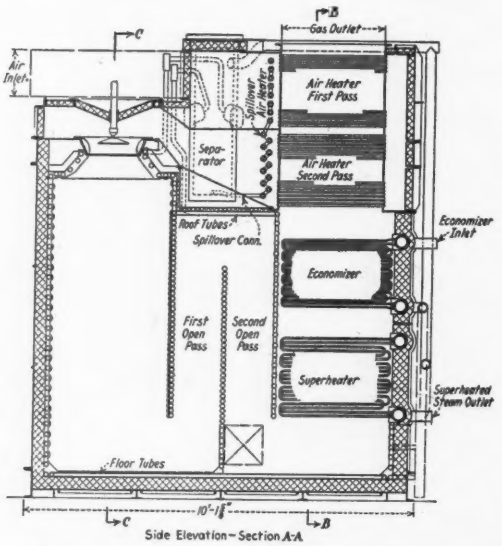


Fig. 4. A vertically fired open-pass unit of the same capacity as the experimental unit tested

of 21,000 lb. of steam per hr, with reasonable combustion efficiency. Although the design capacity for continuous running was for 16,000 lb. steam per hr., the unit ran 40 continuous hours at 21,000 lb. per hr. and was tested up to 22,000 lb. per hr., which was the limit of the blower for continuous operation.

At the normal load rate of 16,000 lb. of steam per hr. the feedwater pressure entering the economizer is 1610 lb. and the steam pressure at the superheater outlet is 1390 lb., there being a 220-lb. pressure drop through the economizer, boiler, and superheater. The steam temperature leaving the superheater at an output of 16,000 lb. per hr. is 870 deg. F., rising to 910 deg. F. at 22,000 lb. per hr. and dropping to 770 deg. F. at 5000 lb. per hr.

Air pressure entering the air heater is 18 in. of water at a steaming rate of 16,000 lb. per hr., which increases to 43 in. at a rate of 22,000 lb. per hr. The air entering the burner is 450 deg. F. at a rate of 16,000 lb. per hr. and 500 deg. F. at a rate of 22,000 lb. per hr. Combustion is complete within this range of output with less than 15 per cent excess air, and combustion rates from 25,000 to 375,000 B.t.u. per cu. ft. of furnace volume per hr.

Efficiency

Boiler efficiency varies from 75 per cent based on the high heat value at a rate of 22,000 lb. per hr. up to 85.5 per cent at a rate of 5000 lb. per hr. These efficiencies are 4 to 5 per cent higher than those originally anticipated from the limited heating surface permitted under the conditions to be met in locomotive design.

The boiler may be quickly placed in service from a completely cold condition, if the auxiliary set is driven from an external source. Tests showed the boiler steaming at reduced pressure within 4 min. and up to full load with normal pressure and temperature after 6 min. more.[1]

Figure 4 indicates an improved design of Steamotive unit after experience with the development unit at Schenectady and Lynn. This boiler is vertically fired. The furnace is circular in cross section. There are two intermediate open passes between the furnace and superheater which require the gases to make three 180-deg. turns. The furnace and two open passes are completely water-cooled with studded or bare-tube construction. The furnace tubes are fully studded and the open-pass tubes are bare or partially studded. The maximum capacity of this boiler is about the same as the original developmental unit.

[1]For a summary of conclusions regarding the application and possibilities of the Steamotive see p. 33 Power Plant Engineering, January, 1937.

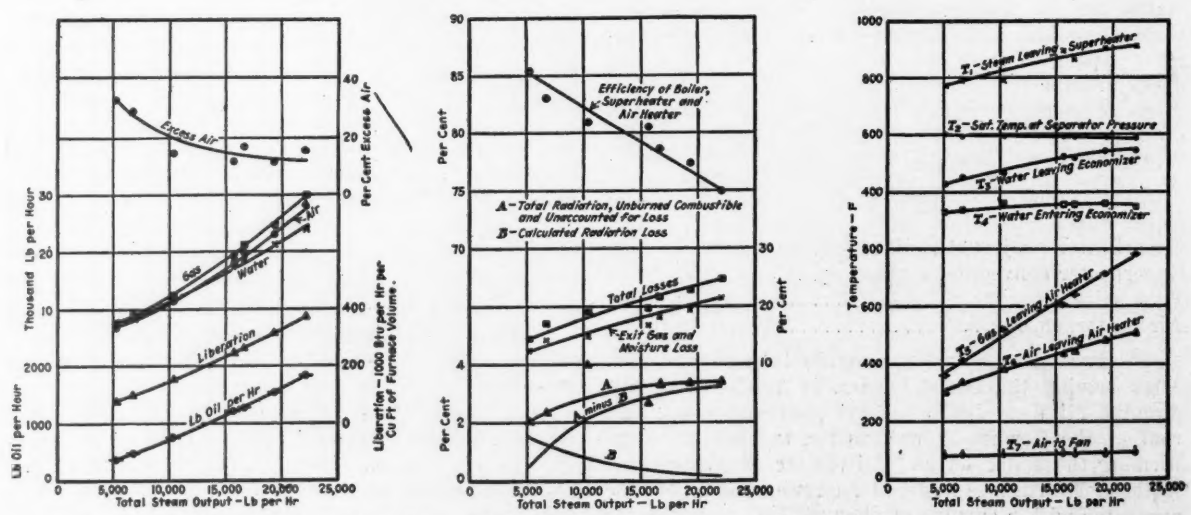


Fig. 3. Some of the test data taken on the experimental unit

Timken's New Fuel Pump

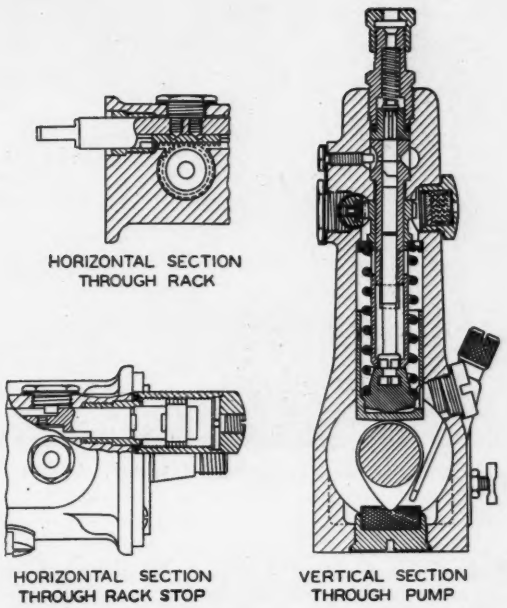


Fig. 1. Details of the new Diesel fuel injection pump. The section through the rack shows the adjustment for individual plungers. The rack stop limits the maximum injection in accordance with altitude. The stop is not shown on the pump section but is the knurled nut at the right of the core in Fig. 2.

THREE YEARS of laboratory development plus a full year of testing in the field preceded the announcement of a high speed solid injection fuel pump for Diesel engines by the Timken Roller Bearing Co. At present these pumps are being made in two sizes for 1, 2 and 6 cyl. engines. The Type A, or small size pump, uses a 4 to 9 mm. range of plunger and is adapted for use on Diesel engines up to approximately 150 hp. and operates at speeds up to approximately 4000 r.p.m. The Type B uses a 5 to 11 mm. range of plungers, is adapted for engines from 110 to 250 hp. and operates at speeds up to approximately 3000 r.p.m.

As will be seen from the accompanying diagrams, these pumps are of the cam operated, helical plunger type. At the lowest position of the plunger the cylinder receives a charge of oil from the feed line, kept filled by a separate pump at the fuel tank. Delivery of the fuel to the engine starts as soon as the plunger covers the inlet port and ends when the helical edge of the annular groove in the piston opens the overflow or by-pass port on the opposite side of the pump cylinder wall to release the pressure to the discharge line. The effective delivery stroke of the piston may be regulated by rotating the plunger to vary the point at which the overflow port is uncovered.

This rotation, under action of the governor, is accomplished by means of a rack rod which extends horizontally along the rear face of the pump, meshing with cut gears on the upper ends of the driving sleeves. The upper or driving sleeve of each piston rotates on the barrel of the pump, and is tongue and groove connected with a lower sleeve which fits on the plunger.

Light helical springs return the plunger, hold the driving sleeves in position and keep the tappet cups against the cam. Tappet cups, of the automotive barrel type, are made of a new steel, recently perfected by the Steel and Tube Division of the company, which contains free graphite. It can be heat treated to provide the extremely hard wear resisting surface desired and the graphite acts as a lubricant. The tappet and spring design used eliminates screw and field adjustments, and depends entirely upon the accuracy of manufacture of the parts to precision standards. Riding as it does on the cam, the tappet spins, holding wear to a minimum.

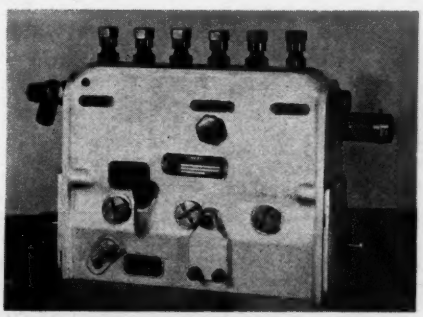


Fig. 2. Front view of one of the pumps for a 6 cyl. engine. The rack stop is at the right of the case, adjustment for individual plungers must be made from the back to discourage tampering by inexperienced mechanics or operators

To adjust the individual metering sleeves on the plungers the rack rod is provided with a series of detachable rack sections which mesh with the gears of the metering or driving sleeves. They may be adjusted independently of each other to obtain uniform angular adjustment of all plungers without removing the rack bar or dismantling the pump by means of two horizontally spaced parallel screws with conical ends, shown in the left hand detail of Fig. 1. Provision for this adjustment is made at the back of the pump housing to discourage attempted adjustment in the field.

A special stop is provided at the end of the rack by a knurled nut by means of which the maximum amount of fuel can be limited according to the altitude at which the engine is working. A series of cotter pin holes is drilled through this nut, the space between each hole representing the change required in adjustment for 1000 ft. change in altitude.

These pumps operate under pressures running as high as 10,000 lb. per sq. in. with a plunger clearance of but 0.000030 in., so the housing, designed to provide the necessary stiffness, is made of special alloy steel. For convenience in installation and in line with American practice, the pumps are made to fit standard bases and connections, all parts being interchangeable and easily replaced when necessary from stock.

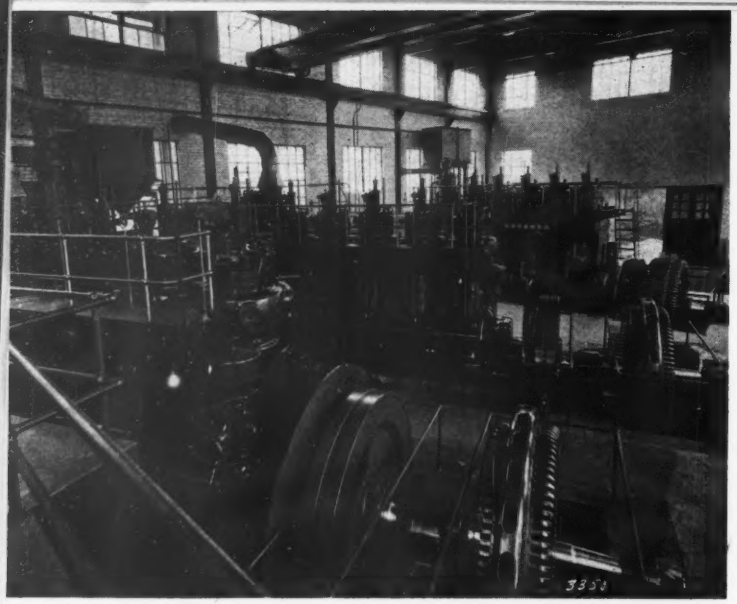


Fig. 1. The new 1250 hp. engine is in the background

ANOTHER

Michigan Municipality carries city and rural load with hydro, Diesel and high line power. 1250 hp. Nordberg latest addition in new plant extension

FOR OVER 42 yrs. the city of Marshall has served its citizens with light and power from its municipal power plant. The system is unusual in that the load is carried by combined hydro and Diesel running in parallel with the public utility operating in that territory. This arrangement, dating back many years to the period when competition between utility systems and municipal plants was less bitter, has been entirely satisfactory to the city, and, to those interested in the development of the power industry regardless of the source of power generation, this amicable arrangement might well be studied in closer detail as a possible compromise settlement of many bitter feuds in various sections of the country.

The original plant, built 1892, consisted of three old type Bull Wheels with horizontal drive shafts. At present the hydro capacity consists of three vertical Leffel wheels, two installed in 1919 and one in 1928, operating under a head of 12 ft. developed by a small concrete dam across the Kalamazoo River within the city boundary. Two of these wheels drive General Electric 144 kw., 0.8 p.f., 3 ph. 60 cycle, 2300 v., 200 r.p.m. generators with separate exciters, the third wheel drives an Allis-Chalmers 219 kw., 0.8 p.f., 3 ph., 60 cycle, 2300 v., 257 r.p.m. generator with a 125 v., 152 amp. direct connected exciter. All three are equipped with Woodward governors.

Two Engines Added

On July 4, 1922, two Nordberg Diesels were added to the system in a new plant built adjacent to the hydro plant as shown by Fig. 2. These engines are 5 cyl., Type VE rated at 550 hp., and each drives a 500 kv.-a. Allis-Chalmers 2300 v., 3 ph., 60 cycle, 225 r.p.m. generator. Separate excitation is provided by two Allis-Chalmers motor generator sets consisting of 45 kw., 125 v. compound wound d.c. generators direct connected to 2200 v., 25 hp. motors.

Control and feeder panels are located on a balcony overlooking the engine room. This switchboard, with the two panels recently added for the new engine, has 13 black slate panels supplied by Allis-Chalmers. The voltage regulator, synchroscope and circuit breakers are General Electric, while the instruments are both General Electric and Westinghouse.

Cooling water for these two engines is taken from the forbay by two 175 g.p.m., 45 ft. head Allis-Chalmers single stage centrifugals driven at 1720 r.p.m. by 5 hp., 220 v. motors. The water is used direct without treatment. A Hydrol unit installed, with the pumps and exciters on the operating floor under the switchboard galley, handles the lubrication oil for all three engines. At 10 t. hand operated Whiting crane serves the entire engine room.

No Transformers

No transformers are installed at the plant, the 2300 v. feeder panels serving the city lines direct from the generator busses, with auxiliary power taken off the distribution lines through small transformers like any other commercial customer.

Division of load between hydro, Diesel and high-line is shown by the chart, Fig. 3, prepared in connection with studies made before the decision to add a third engine was made. The fiscal year runs from

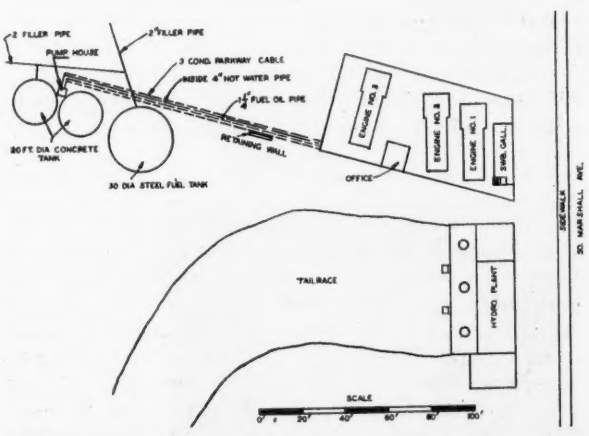


Fig. 2. Property plan showing equipment arrangement. The three water wheels have a combined capacity of 579 kv-a., the three engines 2087 kv-a.

THOUSAND For MARSHALL

April 1 to April 1 and figures for 1936-7 are not yet available to complete this chart. Due to low water, the hydro output last year was limited, but the added engine capacity made it possible to cut down some on purchased power so that this year's operation will show a much larger proportion of Diesel power than will past years.

When the decision was made early in 1936 to add the third engine with the assistance of a $40,886 P.W.A. grant, plus $49,971 of Department money, an extension was made on the original engine plant as shown by Fig. 1. A basement was excavated under this section for the auxiliaries and a small heating boiler which fit nicely into a triangular space provided as shown on Fig. 6. On the operating floor, this triangular space between Nos. 2 and 3 is used for a new glass

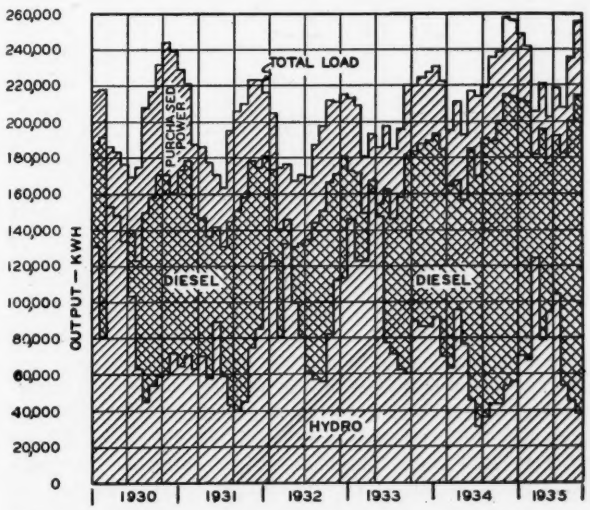


Fig. 3. Distribution of hydro, Diesel and purchased power for several years

enclosed engineer's office. Reference to the property plan will show how this space came about through the angularity of property lines. The first two engines were installed parallel to the street, while the third was installed perpendicular to the railroad in order to straighten out the building lines and provide space for a fourth engine in the same building.

This new engine is a Nordberg 5 cyl., 2 cycle air injection type TA rated at 1250 hp. It drives an Allis-Chalmers 1087.5 kv-a. 0.8 p.f., 3 ph., 60 cycle, 257 r.p.m. generator and a direct connected 125 v., 200 amp. exciter. The engine is equipped with a Woodward Type 1C governor and a Manzel 25 pt. forced feed lubricator. Cooling water for this unit is softened and circulated in a closed system from a soft water storage tank located outside. The softener, a small Kalamazoo unit, is located in the basement, together with the two Allis-Chalmers 250 g.p.m., 50 ft. head, 1750 r.p.m. pumps (5 hp. motors) one for raw water and one for soft water. Cooling of both the lubricating oil and soft water is effected in two Schutte & Koerting heat exchangers also located in the basement at the end of the engine foundation. Immediately below and between the two coolers is the Viking lubricating oil circulating pump.

In addition to the above, the starting air cylinder, auxiliary starting air compressor close belted to a 10 hp. Allis-Chalmers motor and an American Radiator heating boiler fired by a Ray oil burner under control of a Time-O-Stat pressure switch are in the basement.

Fuel oil is stored in a new steel tank of 50,000 gal. capacity, which in January, 1932, replaced two older concrete tanks at a cost of $687.65. A pumping station at the main tank delivers oil to an elevated day tank in the engine room and from there it flows by gravity to a smaller float controlled tank in the basement alongside the engine foundation and handy with a short lift to the fuel transfer pump on the engine. Outside air for all three engines is filtered through American air filters, the fuel oil is metered by National meters, exhaust gas temperatures are read on Alnor pyrometers and engine temperatures on Motoco dial thermometers.

The total cost of the new addition is divided as follows:

Advertising and legal	$ 98.60
Engine, generator, exciter and auxiliaries	69,212.00
Foundation and building	15,418.95
Switchboard and electrical work	3,300.00
Engineering	3,120.46
Total (Material and Labor)	$91,150.01

In addition to serving the city, there are about 8

Electric department production costs for the year ending March 31, 1936. These do not include distribution, general and administrative expense which increases the total commercial light and power load of 2,080,524 kw-hr. to a unit cost of 1.98228 cts. per kw-hr.

			Per K. W. H.
Production Expense:			
Station Labor	$ 6,478.69		
Compensation Insurance	454.98		
Station Supplies and Expense	773.68		
Diesel Engines—Fuel	5,918.30		
Lubricating Oil	685.95		
Repairs	1,065.99		
Depreciation	4,765.63		
Dam, Wheel House and Race—Maintenance and Repairs	120.38		
Depreciation	1,404.89		
Sundries:			
Maintenance Machinery and Electrical Apparatus	38.81		
Maintenance Power House	23.56		
Fuel	92.12		
Depreciation—Machinery and Electrical Apparatus	956.93		
Depreciation—Power House	999.85	$ 23,779.76	
Current Purchases 354000 K. W. H.		6,864.00	
Total Production Cost		$ 30,643.76	
Cost of 2572120 K. W. H. Produced		$ 23,779.76	.92452
Cost of 354000 K. W. H. Purchased		6,864.00	1.9389
Total K. W. H. Generated		2,926,120	
Less: Line Losses	282,827		
Current Consumed by Electric and Water Board	124,776	407,603	
Total K. W. H. Delivered—Applicable to Cost		2,518,517	1.21673c

Fig. 4. Three water wheels are installed operating under a head of 12 ft.

mi. of rural lines in service. Due to the depression the farm load has been disappointing, but a number of summer cottages at the ends of both lines more than justify the construction. For the last report available, for the year ending March 31, 1936, the department made a nice profit and turned $19,000 over to the city for bond retirement. Net rates of commercial light and power amounted to 2,080,524 kw-hr. at a net value of $71,675.03 or 3.4450 cts. per kw-hr. This power cost $41,241.89 or 1.98228 cts. per kw-hr., giving a profit of $30,433.14 or 1.47090 per kw-hr. In addition, the water works used 168,580 kw-hr. credited at 2.00 cts. per kw. showing a profit of $443.23 or 0.2692 cts. per kw-hr. over the unit cost of 1.73708 for this block of power, and gratis service to the city for street lighting, etc., amounted to $5,836.17, leaving a net profit of $25,040.20.

Distribution

Production expense as taken from the report is shown by the table. Other expenses of distribution, office and administration expense brought the total cost

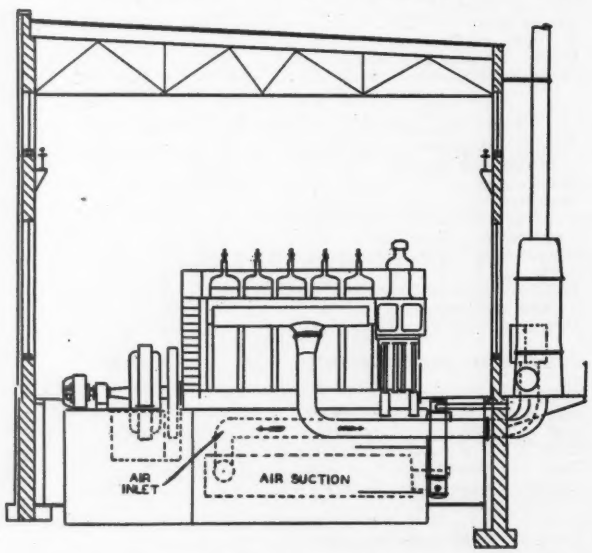


Fig. 5. Cross section of the plant extension. Auxiliaries are in the basement at the far side of the engine

up to the figures used above. The total of 2,518,517 kw-hr. delivered were allocated as follows: Commercial light and power, 2,080,524; Waterworks, 168,580; Street lighting, 219,793; town hall, air port, library and fountain, 49,620. The book value of the system to March 31, 1936, was $413,582.61 and allowing for depreciation and reserve, $223,856.08.

Rates range from 5 cts. per kw-hr. for the first 30 kw-hr. per mo. to 2.5 cts. for all over 80 kw-hr. with a minimum charge of 50 cts. per month. Rural rates begin at 6 cts. and range down to the same as city rates for bills of 54 kw-hr. per mo. Power rates consist of a service charge of 65 cts. per mo. per active hp. connected (also the minimum charge) plus an energy charge of 2.25 cts. per kw. Active horsepower is estimated on a schedule which ranges from 90 per cent of connected load for the first 10 hp. down to 50 per cent for all over 100 hp. connected. During the year 1935-36 there were a total of 1960 meters set for lighting customers and 50 for power customers.

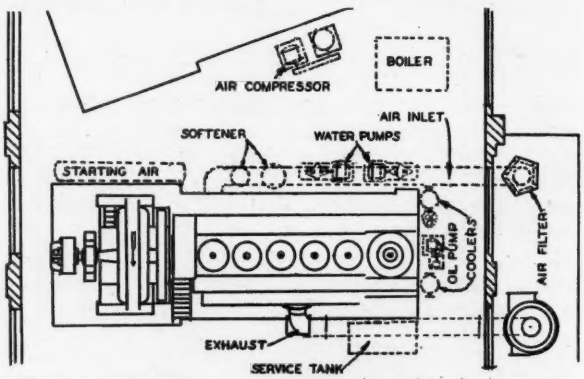


Fig. 6. Auxiliaries for the new unit are located in the basement

The electric light and water department is operated under a board of three commissioners: H. C. Brooks, R. F. Grant and E. B. Moore. The Fargo Engineering Co. of Jackson, Mich., handled the engineering work. Earl Lockwood, formerly assistant superintendent of the department, has been superintendent since the death of P. S. Joy. Mr. Joy, superintendent of the department for 46 yr. and responsible for its rapid growth and successful operation, died in Long Beach, Cal., Jan. 9, 1937, while on a vacation.

"Treatment of Air With Electricity" is the problem set before a new technical subcommittee formed under the Committee on Research of the American Society of Heating and Ventilating Engineers, which recently held its first meeting at the society headquarters in New York to map out a research program directed at discovering if possible, and duplicating in indoor conditioned air, certain intangible qualities which seem to be present in outdoor air giving it a particular zest and life. Discussion at the first meeting revolved around the problem of ozonization, ionization and treatment of air with ultra violet rays which has shown interesting possibilities in the killing of air born disease germs. Reports of the present status and results in this treating indoor air were reviewed as the basis for beginning new investigations and the committee also took up the subject of electrical filtering of air by precipitation processes.

Stoker Development Reaches High Standard

Savings in the boiler room by the burning of lower grade coals and increased steaming outputs.*

By J. G. WORKER
American Engineering Co.

LOOKING about in steam plants in various sections of the country, there seems to be an element of uncertainty as to just what our future steam units are going to look like. There are so many things that designers are trying to put together that engineers are experiencing difficulty in selecting the right thing suitable for their own particular use.

High standards, of course, have been greatly developed, not only so far as the physical appearance of boiler rooms is concerned, but also in their methods of operation. This certainly has brought about savings.

Executives of companies, their engineers and operating departments have all contributed in attaining the present high order of operation of boiler rooms.

What are the things that we are trying to do in the boiler room? It is quite clear. We want to generate steam at the lowest possible cost without sacrificing lower first cost. The purpose of this paper is to give briefly the results of engineering and development, particularly with respect to the stoker equipment.

In general, we find that the average plant is faced with the necessity of using a premium coal in order to overcome the difficulties encountered when a cheaper coal is used. Units of older design may develop difficulties when forced and cause the fire to become hard to manage. In addition, the gas passages around the heat absorbing surfaces may accumulate slag and then the unit is not as efficient or reliable. The result of all outages is interruption and, consequently, a reduction in the reliability, continuous capacity and efficiency that ought to be produced.

Fundamental Specifications

If engineers were called upon to design an ideal fuel burning equipment, what fundamental specifications would such a unit measure up to and what would determine the relative value of the individual items in these specifications? The following list of factors is submitted and they have been arranged in the order of their importance.

1. Reliability
2. Capacity
3. Maintenance
4. Flexibility
5. Fuel Flexibility
6. Efficiency
7. Operation
8. Adaptability
9. Refuse
10. Stack Discharge
11. Space Requirements
12. Obsolescence
13. Price
14. Other Considerations

*Abstract of paper presented before the Engineers' Society of Western Pennsylvania.

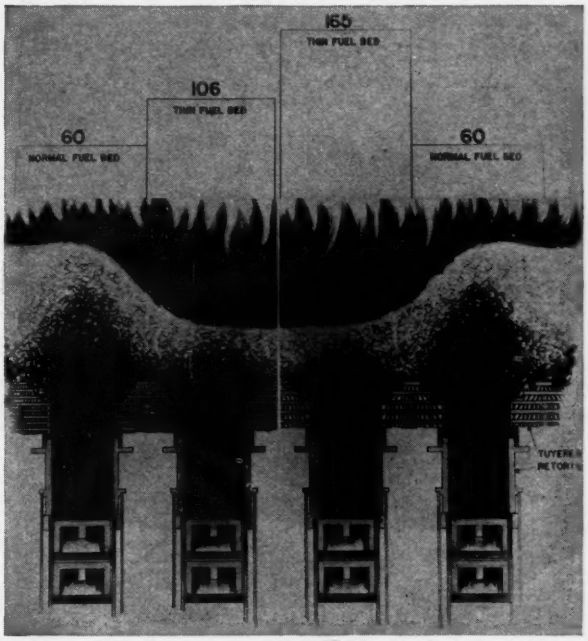


Fig. 1. Cross section through fuel bed of multiple retort stoker

Progress of Stoker Design

That engineers have made progress toward the solution of the problems presented is indicated by the performance of some of the more modern installations of stoker equipment. Efforts have been made and are still being made to produce stoker fired steam generators that will function up to full capacity for 50 out of 52 weeks. Stokers must finally be designed to operate this long. This degree of reliability is also necessary very frequently in order to justify the investment made. Figures indicate that a gross return of 25 to 30 per cent can only be shown when a reliability factor in excess of 90 per cent is attained.

In older designs soft ash sometimes chilled at a level above the air openings in the grate. When this happened it acted as a binder in the fuel bed. This, then, reduced the area of fire through which air could pass. Since the same quantity of air must pass in order to sustain the output desired, the reduction in area resulted in substantially increased air velocities.

Controlling the Air

It will be seen that means for equalizing and controlling the burning rate over the entire area of the stoker are essential to sustained high capacity. The water cooling of the stoker has proved effective to this end and accomplishes the desired result by instantaneously chilling the ash in small pieces rather than cooling it slowly. For these reasons, the fuel bed on a water-cooled stoker is more homogeneous and the burning rates are better equalized.

Developments have also been made in tuyere de-

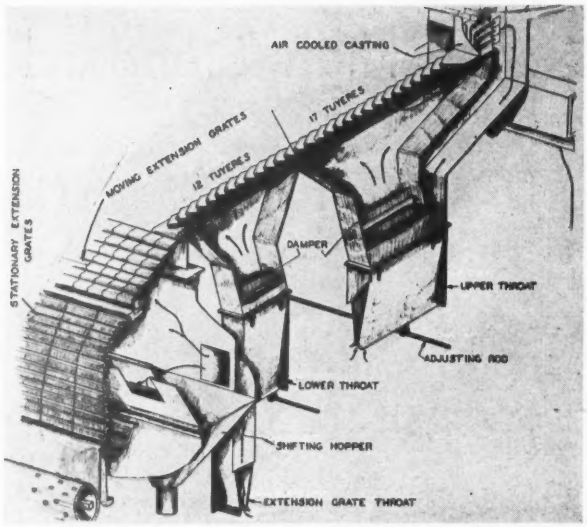


Fig. 2. Air control system of stoker in Conners Creek Station

sign so that the flow of excess air to a weak point in the fuel bed is restricted and, as a result, the air flow through the entire fuel bed is better distributed.

Figure 1 shows a cross section through a typical fuel bed of a multiple retort stoker with the green coal in the troughs or retorts moving upward and over the tuyeres as the fuel moves down the grate.

Above this cross section, a chart is indicated showing the pounds per square foot per hour of coal burning above each section.

In the right hand side, we have a normal fuel bed burning 60 lb. per sq. ft. per hr., and on the next section a thin fuel bed results in an excessive flow of air and sufficient air passes through the fuel bed to burn 165 lb. of coal per sq. ft. per hr., representing the type of condition that has existed in the past.

Considerable research work with air control and distribution has permitted the adoption of a means whereby the normal fuel bed would still burn 60 lb. per sq. ft. Where in the conventional fire, and air supply sufficient to burn 165 lb. would exist, with improved air control, the coal burning rate would be limited to 106 lb. as shown. This system has a marked effect on the behavior of the fuel bed, in actual practice, and by limiting the maximum combustion rate in spots, raises the average for the whole fuel bed substantially so that increases of the order of 30 per cent or more in the average coal burning rate can be maintained quite easily. The practical value of this to the operating man is obvious. It means that the output from a stoker of given grate area can be materially increased with a corresponding improvement in the efficiency all along the line.

This has been worked out in a practical way by the Detroit Edison Co. at the Conners Creek Station. The Edison engineers have now had a long time operating experience, and they have discussed their experience before engineering societies and have given the benefits that have come to them through the controlling of fuel bed conditions. The air control (Fig. 2) is a system whereby the surface of the stoker is divided into a large number of small areas and the flow of air to each area is separately measured and controlled. In some cases the control is handled manually and in some cases automatically.

It will be seen that all of these steps are toward the same objective; namely, the equalization of burning rates over the entire area of the stoker. This equalization increases the minimum burning rate and decreases the maximum burning rate and thus makes possible higher average burning rates and consequently higher capacities.

Maintenance

The reduction of maintenance both as to cost and time required is very closely related to reliability. Recent designs have materially extended the amount of water cooling used in furnace design. Water cooling has been extended to cover the entire top surface of the fuel supporting area of the stoker. This step has had far-reaching results. When the air admitting openings are closed and the normal flow of cooling air is interrupted, the result is the destruction of the furnace parts. The water cooling prevents the closing of air ports, and the result is reduced maintenance.

The ability to follow the steam demand up and down quickly is an inherent advantage of the underfeed stoker. The large reserve of coked coal in the fuel bed can be burned at the operator's will by regulating

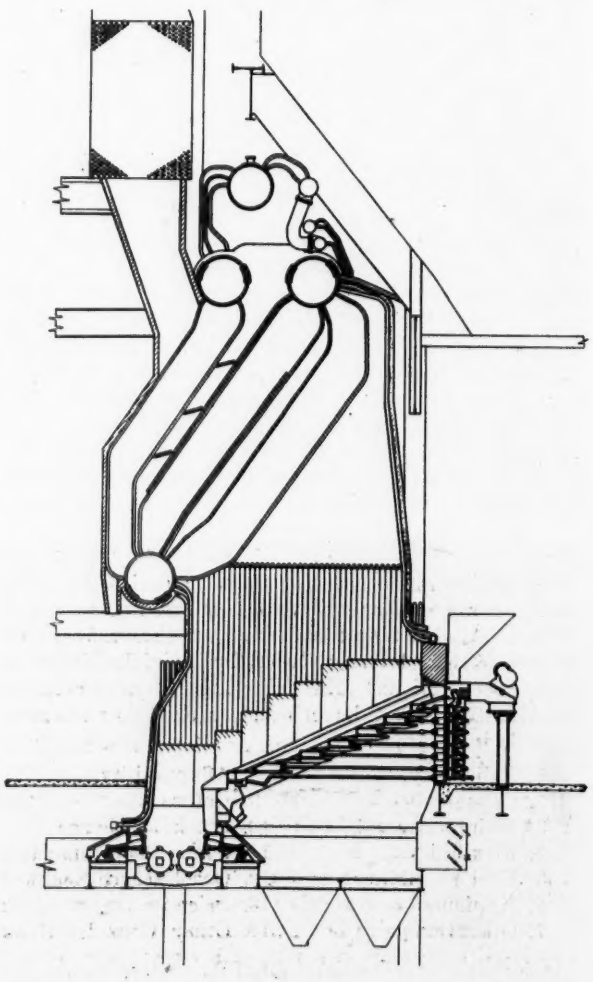


Fig. 3. Cross section of Hudson Avenue boiler and furnace

the air flow through it. The strides that have been made toward a more homogeneous fuel bed and better air flow control, still further expand the possibilities along these lines.

Perhaps the most important characteristic of coal from the standpoint of its use in modern steam generators is the fusing temperature of its ash. This characteristic affects the fuel bed and efficiency of the passages in the boiler and superheater. Water cooling has modified this problem. The best result has been attained as a result of the more homogeneous fuel bed equalizing the air flow, thus reducing localized high air velocities. At the higher burning rates, modern tuyere design and air control contribute to this improvement. Other characteristics of coal such as moisture and volatile content do not offer as serious a problem. The method of fuel introduction is inherently suited to the distribution of these portions of the fuel under and through the entire area of the fuel bed. Ignition can be adjusted and maintained at all ratings regardless of the amount of water cooling in the furnace.

Efficiency

Maximum efficiency has not changed materially since 1926 when it reached well above the 90 per cent mark. The curves for modern installation, however, are flatter and high efficiencies are maintained over a wider range of output. This results directly from the progress that has been made toward the equalization of fuel bed ratings. Efficiencies were formerly reduced at the higher rates, due to the various fuel bed disturbances that have been described.

Distinct strides have been made in the simplification of operation of high capacities and high efficiencies. Facilities for the correction of fuel bed conditions have been brought to the front end of the stoker and are easily made during operation. Modern tuyere designs and air control automatically modify the attention formerly required, thus reducing the number of corrections that must be made. In conjunction with the air control, gages measuring the air flow to the individual areas of the stoker bring visually to the operator a picture of the conditions that exist in the fuel bed. Premature admission of air to the fuel is prevented by a sealing of retorts below the tuyere area, better alignment and fit of the parts resulting from the increased use of steel and welding, and better machining methods all contribute to the ruggedness of the machine and its ability to do with less attention.

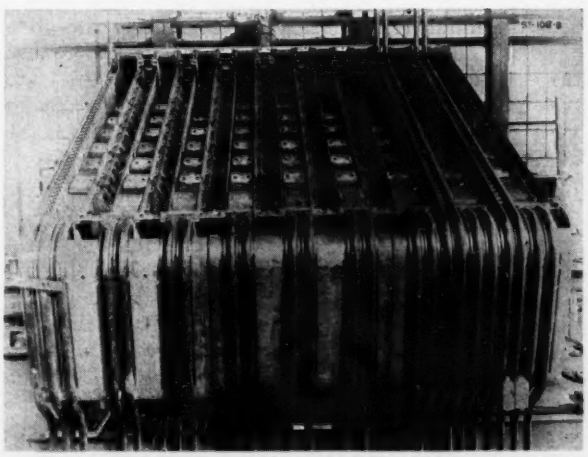


Fig. 4. Shop photograph of water-cooled underfeed stoker

Due to the water cooling of the stoker and its use with a wide range of fuels, it is adaptable to a wide range of boiler and furnace design. Advantages can be taken of the most suitable design to meet the particular conditions encountered in a particular application.

Ashes discharged by the water-cooled stoker are somewhat smaller in size than formerly and can be conveniently and cleanly handled and frequently have a sales value for use as grading and fill. It gives little trouble after it is collected and can be transported.

Fly ash discharge from the stoker fired steam generator is not objectionable in amount and is of such a size that it can be collected comparatively easily and inexpensively. The bulk of the ash remains on the grate and is automatically discharged by the mechanism provided for this purpose.

When coal is burned on an underfeed stoker, it remains practically stationary on the grate. Air for its combustion sweeps over it. This characteristic provides the scrubbing action and mixing of the air and the fuel within a localized point and a relatively short distance. Consequently, a large furnace is not essential to the complete combustion of the fuel. This fact makes possible the production of a large quantity of steam with a relatively small consumption of space and volume. Hudson Avenue (Fig. 3) tests show about 2020 lb. of coal were burned per hour per foot of furnace width for maximum continuous capacity on their stoker. The furnace width is 26 ft., and each furnace has 694 sq. ft. of projected grate area.

Oxy-Acetylene Pipe Welding

Report of a committee on welding brings out the following points: Use of a number of flames in the welding tip distributes heat more effectively so that the welding puddle is more easily controlled, allowing of increased speed and reduced gas consumption. Special fittings for welding and use of the multi-layer method have increased ease and assurance of weld quality.

S. T. Seeley of Midwest Piping and Supply Co., in discussion of piping systems, emphasizes the attention which engineers are giving to the design of piping systems with the same care that is given to selection of prime movers and auxiliaries, to secure permanence, flexibility in operation and low initial cost. Shop fabrication, especially of an intricate piece, results in a large saving over field welding, even though it may involve some problem in placing the fabricated piece in position.

Flanged and screwed joints will always be used to some extent and choice of types such as the Van Stone, welded flange and others should be carefully made.

For low-pressure work, cost of welding is a factor and small piping is usually installed with screwed fittings.

Welded construction has the advantage that risers and branches can be run without regard to location of mains, also mains without regard to branches, since connections can always be made by turns and angles fabricated to fit.

Electron Tubes— Principles and Applications

Part XIII. Principles and characteristics of the four electrode or screen grid tube, secondary emission and its effect on the screen grid tube's characteristics.

By A. W. KRAMER

HAVING CONSIDERED the principle of neutralization of electron tube amplifier circuits, we shall now return to a consideration of the screen grid tube which was referred to at the beginning of the preceding article. Our digression into the subject of neutralization of amplifier circuits was not unintentional, for a knowledge of the principle of neutralization aids in obtaining a better understanding of the functions of the screen grid tube. This method of approach is better also from a chronological standpoint since the screen grid tube did not come into general use until some time after neutralized amplifiers had been used in practice to a considerable extent.

Before we consider the screen grid tube in this article let us recapitulate briefly and list the factors which led to the development of neutralized amplifiers and finally to the screen grid tube. 1. The thing that limits the use of the triode as an amplifier at extremely high frequencies is the inter-eletrode capacity of the tube. 2. To overcome this limitation, neutralizing cirsuits were developed which, in effect, neutralize the capacity of the tube, thus permitting stable amplifier operation even at high frequencies 3. The neutralized amplifier despite its advantages over un-neutralized circuits, obviously is a make-shift affair and it was clearly apparent from the beginning that if a tube could be developed which would exhibit no capacity effect, neutralization would be unnecessary and circuits would be much simpler. This brings us once more to the screen grid tube.

Suppose that in an ordinary triode, a second grid, made in the form of an electrostatic shield, is placed between the control grid and the plate as shown in Fig. 1 and suppose further that this second grid is grounded. Since this second grid entirely surrounds the plate it forms an "electrostatic shield" around the plate and prevents any fluctuation of plate potential from affecting the grid; in other words, it practically eliminates the capacity effect between the grid and the plate. It does not, however, prevent electrons from the cathode and under control of the control grid from reaching the plate. In practice, the "screen" grid is not grounded directly as shown in Fig. 1, but this serves to illustrate the principle involved.

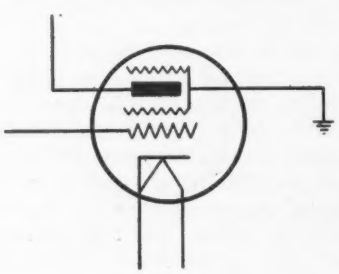


Fig. 1. Diagrammatic representation of the screen grid tube

Quite obviously it is not practical to entirely shield the plate by a screen of this kind since that would prevent the input voltage from reappearing in the plate circuit but the screen can usually be made to reduce the capacity effect to a very low value—essentially to zero as far as "feed back" is concerned. In triodes with grid plate capacities of from 2 to 8 m.m.f.s. the addition of the screen grid will result in capacities of from 0.1 to as low as 0.003 m.m.f.s.

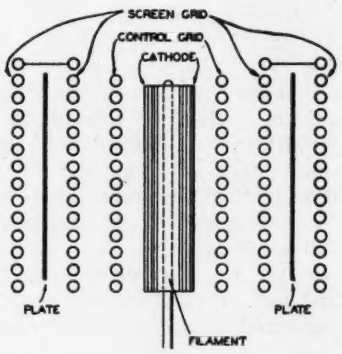
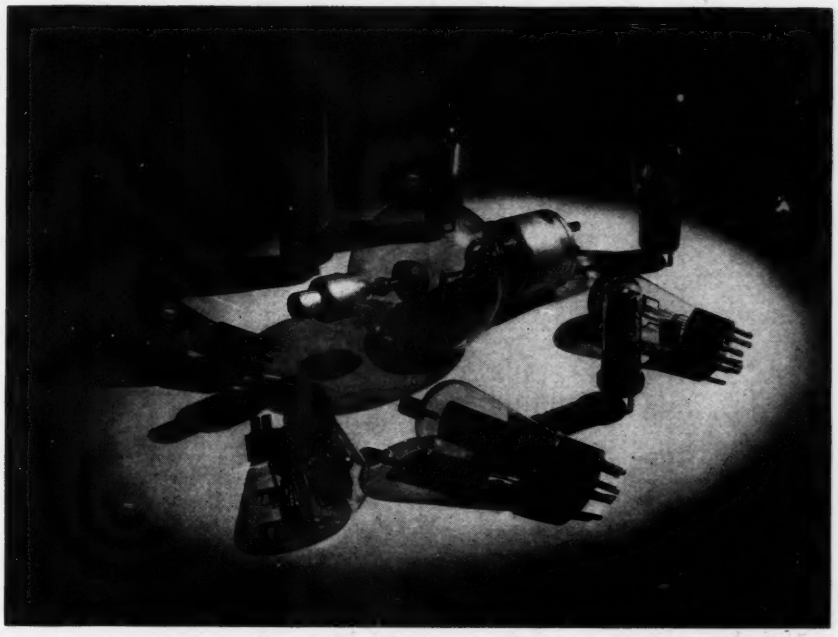


Fig. 2. Cross section, showing one arrangement of a screen grid tube. In this case the screen completely surrounds the plate

The mechanical construction of the screen grid varies with different types of tubes. In the early tubes, the screen grid consisted of two helical grids close to the plate, one inside and the other outside the plate and connected together. In later tubes in some instances the outer screen was dispensed with. Such tubes as generally used today are surrounded by a metal can which is grounded and this prevents fluctuations of the plate voltage from reaching the input circuit of the tube. A diagram of a screen grid tube in

New tools for use in industry



Photo, Westinghouse

which the plate is entirely surrounded by the screen is shown in Fig. 2.

The screen grid is usually maintained at a positive potential somewhat lower than the plate potential by connecting it to a suitable point on the power supply, as shown in Fig. 3. It is therefore not at ground potential so far as the plate current is concerned but a by-pass condenser is usually connected across the screen grid and ground connection so that the screen is at ground potential insofar as the high frequency current is concerned. If the capacity of the by-pass condenser C in Fig. 3 is, say, of the order of 1 microfarad, the impedance between screen and ground will be less than 1/6 of one ohm; it is evident, therefore, that with such a low impedance to ground the screen potential cannot fluctuate with respect to ground. The screen-grid potential is usually about one-third less than that on the plate.

Since the effect of the screen grid is to neutralize the capacity effect of the tube, it is evident that no neutralization is required in an amplifier circuit using screen grid tubes. The circuits, therefore, are much simpler and are more suitable for operation over a wide frequency range.

From the foregoing it might be inferred that the introduction of the screen grid into the electron tube, by eliminating the troubles due to "feed back" at once removes all limitations in the use of tubes as amplifiers. In this instance, however, as in many other cases of a similar nature, the solution of one problem introduces others of a different character. The extra grid, while a valuable ally in suppressing "feed back," is not entirely free from entangling alliances in other matters. Since the screen grid is maintained at a positive potential, it attracts electrons and this, under certain conditions, causes difficulties.

Ordinarily the electrons emitted by the cathode are accelerated toward the plate grid as in the simple triode. First they speed through the control grid and into the region of the positive screen grid. By this time they usually have acquired sufficient velocity to enable them to rush on through the screen grid field to the plate. The action of the control grid is exactly as it is in the triode. Most of the electrons which the screen grid attracts pass through its meshes and go on to the plate which is more positive, so that while the screen grid serves as an almost perfect electrostatic shield it intercepts only a relatively small proportion of the total electron flow.

At certain times, however, under a.c. operation, the plate potential may be reduced to a value lower than the screen and then the electrons would not go on to the plate, but would stop at the screen, or having once gotten past the screen and close to the plate, they would turn about and return to the more positive screen. Furthermore, if an electron impinges upon the plate with sufficient velocity to knock another electron out of the plate, as is often the case, this electron will be drawn into the screen. This "splashing" out of electrons from the plate by the impact of high speed "primary" electrons, is known as secondary emission. When the plate is at the same or higher potential than the screen such secondary electrons are drawn back into the plate, but if the plate is at a lower potential than the screen all of the secondary electrons (and there will be countless millions of them) will be drawn to the screen.

The net result of this action is to produce a current from the plate to the screen. This entirely changes the characteristics of the screen grid tube as compared with the usual triode. Referring to Fig. 4, which is the characteristic curve of a typical screen grid tube with zero control grid voltage and a constant screen grid potential of 83 volts, it will be noted that at plate potentials appreciably lower than the screen grid voltage the plate current actually reverses. In the region from 0 to approximately 10 v. the plate current increases with an increase in plate voltage. Increasing the plate voltage further, however, results in a decrease in plate current and from about 30 to 70

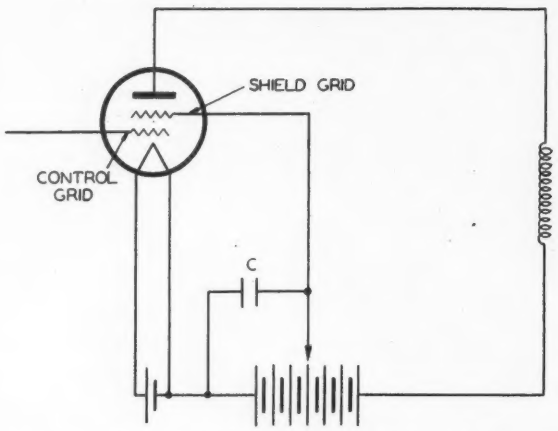


Fig. 3. The screen grid is usually operated at a positive potential, slightly lower than the plate potential, by connecting it to an intermediate point on the plate supply

v. the plate current actually reverses. The reason for the upward slope of the curve between 0 and 10 volts is due to the fact that at these low plate potentials the electrons are unable to acquire sufficient speed to cause secondary emission from the plate. At slightly greater plate potentials, from 10 to around 83, there is secondary emission and the plate loses secondary electrons to the screen. Beyond 83 volts, the plate is at a higher potential than the screen and as a consequence it is able to capture more and more of the secondary electrons as the plate voltage increases. In the region where the plate current is negative, for each primary electron that reaches the plate, more than one secondary electron is lost to the screen grid.

The process of secondary emission at the plate is one that closely resembles the process of ionization described in an earlier chapter.[1] The high speed electrons from the cathode act as projectiles and their impact upon the material of which the plate is made is such that free electrons and electrons belonging to atoms of the plate material are smashed out of the plate. If the speed of the primary electrons is low, only one secondary electron may be driven out of the plate, but if the speed is higher, two, three or even more secondary electrons may be released with each impact.

From this it is evident why the plate current actually reverses under certain ratios of screen grid to plate voltages. This action of secondary emission is of course also present in ordinary triodes, but in triodes the secondary electrons are all drawn back into the plate. In the case of the screen grid tube, however, they can either go to the screen grid or to the plate and if the potential of the former happens to be lower or at approximately the same potential as the plate they will go to the screen. Only by making the plate potential sufficiently higher than the screen potential can all of the secondary electrons be re-captured by the plate.

Although the characteristics of the screen grid tube, as shown by Fig. 4, appear rather complicated as compared to the characteristics of a triode, they depend upon a relatively small number of factors. The primary electrons travel in substantially straight lines away from the cathode and therefore divide between the screen grid and the plate in proportion to the projected areas of the screen grid and plate structures. The result is that for any particular tube each electrode will always receive the same fraction of the primary electrons irrespective of the cathode voltage or the magnitude of the total space current. The number of primary electrons received by an electrode, therefore, is proportional to the total space current.

The number of secondary electrons produced both at the screen grid (for secondary electrons are also produced by impact of primary electrons on the grid) and at the plate is proportional to the number of primary electrons received by the electrode and also, roughly, to the electrode potential. The subsequent flow of these secondary electrons is then determined by the screen grid and plate potentials.

[1]Part VI, July 1936 issue, p. 410.

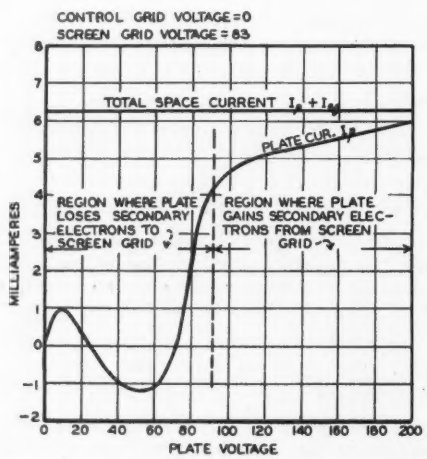


Fig. 4. Typical plate current characteristic of a screen grid tube

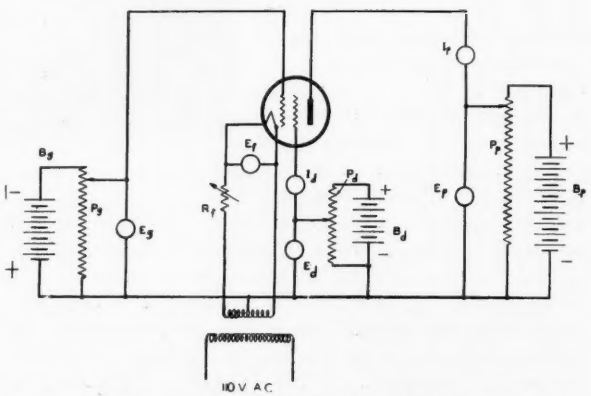


Fig. 5. Circuit diagram for determining the volt-ampere characteristics of a four electrode or screen grid tube

P_g = Grid circuit potentiometer (2500 ohms, 0.3 amp.)
B_g = Grid battery (60 v.)
E_g = Grid voltmeter (0 to 50 v. d.c.)
E_f = Filament voltmeter (0 to 10 v. a.c.)
R_f = Filament rheostat (6 ohms, 5 amp.)
I_p = Plate ammeter (0 to 100 ma., d.c.)
B_p = Plate battery (0 to 400 v.)
P_p = Plate circuit potentiometer (6400 ohms, 0.3 amp.)
E_p = Plate voltmeter (0 to 500 v., d.c.)
I_d = Screen-grid ammeter (0 to 10 ma., d.c.)
E_d = Screen-grid voltmeter (0 to 250 v., d.c.)
E_d = Screen-grid battery (0 to 180 v.)
P_d = Potentiometer (2500 ohms, 0.3 amp.)

When the screen grid is appreciably more positive than the plate practically all of the secondary electrons produced will be drawn to the screen grid. When the plate is more positive than the screen grid, however, only a part of the secondary electrons produced at the screen grid are drawn to the plate. This is due to the fact that most of the screen-grid secondary electrons are produced on the side of the screen grid that is away from the plate and so are partially shielded from the attraction of the plate by the screen grid. When the plate is the most positive electrode it is, therefore, able to attract only a portion of the secondary electrons from the screen grid, this proportion becoming larger as the potential of the plate with respect to the screen grid is increased. The result of these factors is that with given screen grid and plate potentials the ratio which the current received by either electrode bears to the total space current is roughly constant irrespective of the magnitude of the total space current, but that the fraction of the total space current received in any particular case depends very greatly upon the relative (and also the absolute) electrode potentials.

These relations need not necessarily be remembered but a knowledge of them will aid in forming a clear conception of the action of the screen grid tube. Those who are interested and wish to study the action of the screen grid tube in greater detail are referred to other sources of reference.[2]

As in the case of the triode, a comparatively simple circuit may be set up for studying and determining the characteristics of the screen grid tube directly. Such a circuit is shown in Fig. 5. This circuit, as will be seen, contains all the necessary batteries, potentiometers and meters for varying and measuring the potentials and currents in the circuit under various conditions. The filament is supplied with alternating current through a small step-down transformer. Three batteries are provided, one B_g for applying voltage to the control grid; another B_d for applying voltage to the screen grid; and a third, B_p for furnishing potential to the plate. The voltage from each of these batteries is controlled by potentiometers. For any particular tube, the filament voltage should be held constant.[3]

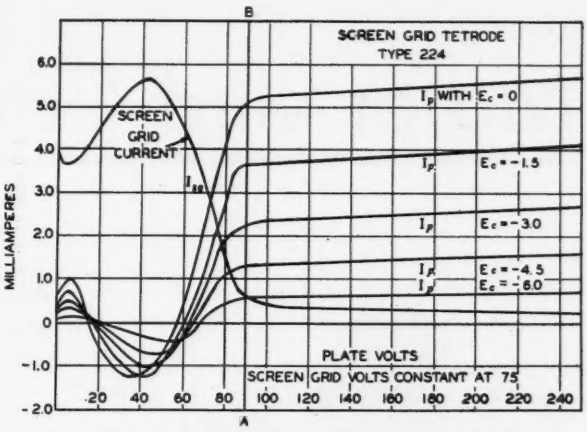


Fig. 6. Plate current curves of an ordinary screen grid tetrode

By means of such a circuit it is possible to obtain a series of curves such as shown in Fig. 6. This shows the plate current curves under various conditions of control grid voltage but with a constant screen grid voltage. Another set of curves can be obtained by varying the screen grid and plate voltages. Such a family of curves is shown in Fig. 7. These appear complicated but when studied will be found only little more complicated than a family of curves for an ordinary triode. They are presented here not so much for actual study as to familiarize the reader with their appearance and so that when and if he ever finds himself in a position where it is necessary to determine the suitability of certain tubes for certain purposes he will not be discouraged by their formidable appearance.

Fundamentally, it will be obvious, the addition of the screen grid does not alter the triodes primary function—that of amplification. The screen grid tube is an amplifier just as is the triode but with certain limitations of the triode removed. The phenomenon of secondary emission it is true introduces new difficulties at least under certain conditions of voltage but these can be anticipated and in some cases it has actually been put to good use. In the next article we shall see how even the wasted part of the screen grid tube characteristic can be reclaimed.

[2]Radio Engineering. By Frederick Terman, McGraw-Hill Book Co.
Electron Tubes. By John H. Morecroft. John Wiley and Sons Co.
Electron Tubes in Industry. By Keith Henny. McGraw-Hill Book Co.

[3]For detailed directions in setting up this circuit and making the necessary measurements, the reader is referred to Experimental Electronics, a booklet of laboratory experiments on electron tube theory published by the General Electric Co.

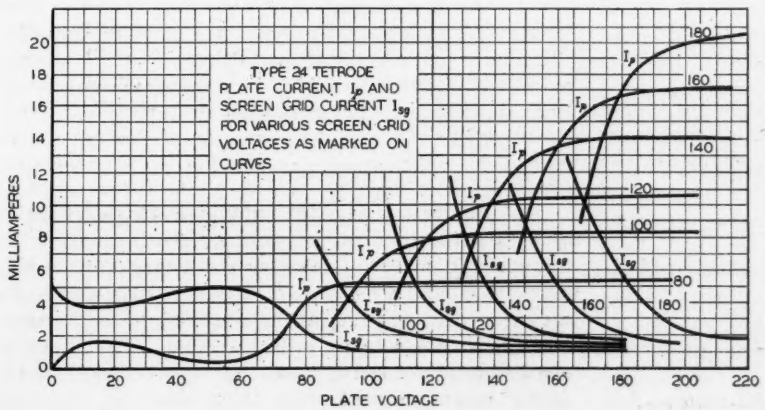
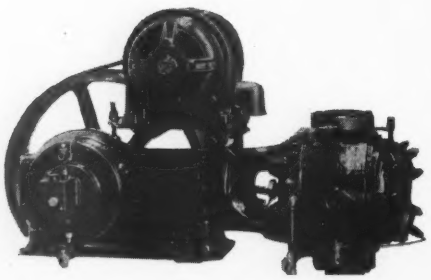


Fig. 7. Characteristics of the ordinary screen grid tube operated over a wide range of screen and plate voltages

Motor and Control Equipment

PART I **A practical discussion of the types and characteristics of compressors available and motors suitable for driving these compressors. A second article dealing with control equipment for compressor motors will appear in a subsequent issue.**



By J. M. BARTHOLOMEW

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IN THE selection of motors for use in driving compressors, it is necessary to know, first, the characteristics of the compressors and, secondly, the characteristics of the various types of motors and control equipment available.

Compressors may be roughly divided into three general classifications. First, the small high speed, single acting, one or two stage compressor which is used in small industrial plants, small construction projects and in mines. These compressors are generally operated only intermittently and are generally applied where portability or low cost is of greater importance than great length of life.

The second classification covers single stage double acting compressors of the horizontal or vertical type. These compressors are used on jobs where the demand for air is small, or where the first cost is of primary importance. These machines are generally designed for long troublefree service but are purchased where size or intermittent use would not justify the purchase of the third class of compressor.

The third compressor classification includes large two stage, double acting, heavy duty machines for installation in large industrial plants, on large construction projects or for primary sources of air at mines or power plants For such installations, it will be apparent that low operating cost is a primary consideration and that long troublefree service is necessary.

It is reasonable to assume that the selection of motors for these compressors will be determined by the same considerations which govern the choice of the compressors.

Motor Requirements

Contrary to some other motor applications, the maximum power required for a motor driving a compressor is very nearly the same as the full load power requirement. Safety valves on the compressor limit the maximum terminal pressure and therefore limit the load which can be imposed on the motor. Any accident, such as broken valves or other conditions which might increase the load on the motor are accidents which require that the drive be shut down and it is therefore desirable to have the overload relays set to trip off the motor in such an event. On other drives, such as hoists or machine tools, it is often desirable to heavily overload the motor for short periods of time. In such cases maximum torque and other motor characteristics are of importance.

On a compressor drive motor temperature rise is a primary consideration and is the factor which limits the load the motor can carry. For example, it might be entirely possible to use a 20 hp. induction motor on a compressor which requires 30 hp. when operating fully loaded, if the portion of the time when the compressor was loaded was 75 per cent of the total time or less. For this reason it is impossible to definitely say that one compressor is better than another because it is recommended for use with a definite motor horsepower.

Types of Motors Available

For compressor drives, there are in general three motor classifications. The first Induction, the second Direct Current, and the third Synchronous motors. Under the first classification we find two types of motors, the Induction Squirrel Cage and the Induction Slip Ring. Synchronous and Direct Current motors may both be further divided into the small high speed type and the large low speed heavy duty type.

Induction Motors

The Squirrel cage induction motor is a motor which derives its rotor magnetism by transformer or induction action. The stator or stationary part of this motor is wound with coils arranged to give a rotating magnetic field and the magnetism induced in the rotor causes the rotor to be pulled around. The speed of the rotor cannot quite equal the rotative speed of the stator magnetic field since there must be a certain

For Compressor Applications

amount of lag or slip to allow the rotor winding to cut the lines of force of the stator to induce the magnetic field in the rotor. This slip fixes the definite full load speed.

An undesirable characteristic of the induction motor is its slow power factor, especially at low loads. This has brought about the various power factor clauses in power contracts and these in many instances make the selection of other types of motors more desirable.

Squirrel Cage Type

The Squirrel cage induction motor is so called because of the fact that the bar winding on the rotor is of the same general appearance as the old squirrel cage. It is the least expensive type of motor obtainable in the higher speed range when compared with other motors of the same horsepower and speed. Standard motors for a compressor drive are of the general purpose type which means that operating continuously at full load the temperature rise will not exceed 40 deg. C. above room temperature. Because of this general purpose or low temperature rise rating, the motor can be used for compressor loads up to 15 per cent above the nameplate rating in special cases, and under continuous load the temperature rise will not exceed 50 deg. C. This does not mean that every compressor application should take advantage of this motor reserve. Longer motor life and somewhat better efficiencies justify the selection of a motor for a compressor drive which will operate at the rated 40 deg. rise.

At altitudes above 5000 ft. the motor does not cool quite so well and even with the 40 deg. rating the temperature rise of the motor may be 45 deg. or 50 deg. even though the compressor horsepower is considerably reduced at the altitude. The compressor load is a pulsating load and the full load current of the motor will be somewhat higher than the rated full load current as stamped on the motor nameplate, since the latter is the continuous steady load value. This increase in current causes a corresponding increase in motor temperature and this again is a good reason for not exceeding the nameplate rating of the motor to take advantage of the 15 per cent reserve factor.

Squirrel cage induction motors are divided into several further types, only two of which are used for compressor drive. The first is the normal torque, normal starting current motor and the second is the normal torque low starting current motor.

In general, it is permissible to start small normal torque normal starting current motors on full voltage using only a line switch. Above 5 hp., the starting or inrush current will be undesirable and will be likely to cause lights to blink if the motor is thrown directly across the line. Above 5 hp. recommend reduced voltage starting. For motor horsepowers between about

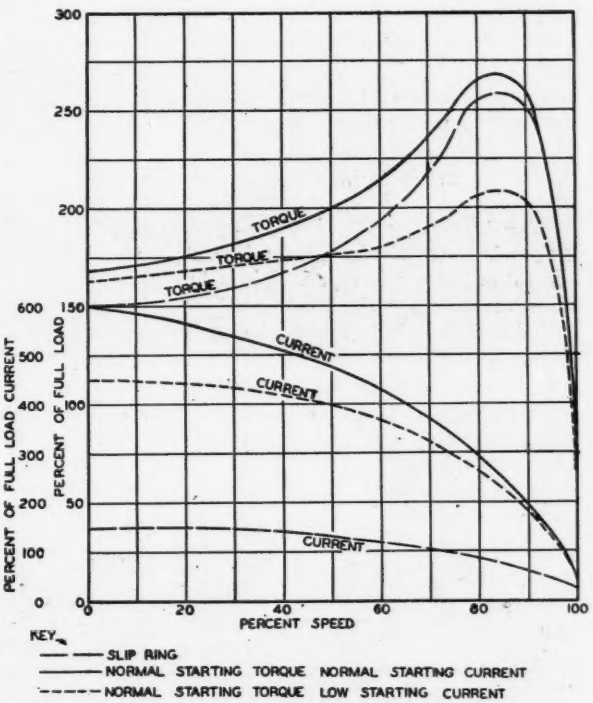


Fig. 1. Induction motor characteristics. Squirrel cage and slip ring types

5 hp. and up to and including 30 hp. the motor builders offer a normal torque low starting current motor which can be recommended for use with a full voltage starter. Some municipalities and some small power companies will insist that starting currents be limited to definite percentages of full load current. The plant engineer must be familiar with local requirements.

For motors rated 40 hp. and above, the shock of throwing the motor on full voltage will be objectionable to most power companies or plant engineers. It is, therefore, a general policy to use the first type, that is, the normal torque, normal starting current motor, and use some type of reduced voltage starter. The question may arise why use the normal torque, low starting current motor at all. The reason is that the full voltage type of starter is generally much less expensive than a reduced voltage starter. The price of a full voltage starter and a normal torque low starting current motor will be less than the price of a reduced voltage starter and a normal torque, normal starting current motor.

Squirrel cage induction motors may be used for direct connection to small compressors and for belt driving compressors of the larger size. Price, simplicity, low maintenance cost, and widespread use in other lines has greatly increased the demand for the Squirrel Cage Induction motor. As a matter of fact,

price consideration during the past few years has led to the use of this motor for some applications where the synchronous motor or the slip ring motor would ordinarily be recommended.

A general rule for applying the squirrel cage motor will be to consider its use, first, and then consider whether or not other available types of motors are preferable for reasons listed under the heading of these other types. If it is definitely decided that an induction motor is feasible, consider the motor size together with any price consideration or power company regulations, to determine whether a normal torque, normal starting current motor, or a normal torque low starting current motor should be applied.

Slip Ring Induction Motors

The Slip Ring or Wound Rotor Induction motor differs from the Squirrel Cage Induction motor in that the rotor has a winding which is brought out to slip rings or collector rings. Instead of being short circuited by heavy end rings as the squirrel cage, the rotor winding is short circuited through a resistance which may be varied by the use of a drum switch or by contactors operated in a definite time sequence. Since the slip ring motor cannot be operated at reduced speed except by the application of a heavy load together with increased resistance in the secondary winding, this motor is considered only for constant full load speed for compressor drive.

The slip ring motor has two very desirable characteristics. The first is that the starting torque can be limited by the use of the secondary resistor and the second is that the starting current or inrush current is limited by the same means. It is therefore possible to insert resistance in the secondary circuit and throw the primary circuit or primary motor leads directly on full voltage. When this is done the motor starts off slowly and smoothly, and can be gradually accelerated as the resistance in the secondary circuit is reduced. See current and torque characteristics in Fig. 1. Because of the fact that this motor has a somewhat higher price than the Squirrel Cage Induction motor and still has essentially the same power factor and efficiency characteristic the application of the motor to compressor drive is limited in general to the following classification.

1. Because of its desirable torque characteristics the slip ring or wound rotor motor is particularly suitable for use on large heavy duty compressors. The starting equipment is relatively simple, primary leads being connected to the lines by a contactor or oil switch and the motor brought up to speed by a drum switch or series of contactors in the secondary circuit. This motor starts without undue line surge and accelerates the compressor smoothly to running speed. The large heavy duty compressor is designed to last for many years and the motor should therefore also be of a type which will start the unit day after day without throwing an undue strain on the belting or bearings. Of course, space and power factor consideration have led to the use of the direct connected, engine type, synchronous motor for this compressor drive, but whenever belt drive will be used and whenever power factor or space considerations are not important the slip ring motor will be selected for this compressor classification.

2. For semi-portable installations, particularly on construction projects, the slip ring motor is particularly suitable. Generally 2200 v. distribution lines will be available at these construction projects and the slip ring motor may be used with an oil switch and the 2200 v. motor applied to this power system, making it unnecessary to have a transformer. The secondary control, of course, is at low voltage. In sizes around 150 hp. or greater the slip ring motor will be very little more expensive than the squirrel cage motor when the difference in cost of starting equipment is considered.

Synchronous Motors

Synchronous motors of both the high speed and the slow speed type obtain their rotor excitation or magnetizing current from a separate exciter or other direct current supply. These motors do not require magnetizing current as does the induction motor and they are therefore primarily used to obtain a high plant power factor. By over exciting either the high or slow speed synchronous motor, additional leading power factor current may be obtained. This is desirable only when there are a large number of induction motors or other low power factor load near the synchronous motor so that the excess or leading power factor current produced by the synchronous motor can be used

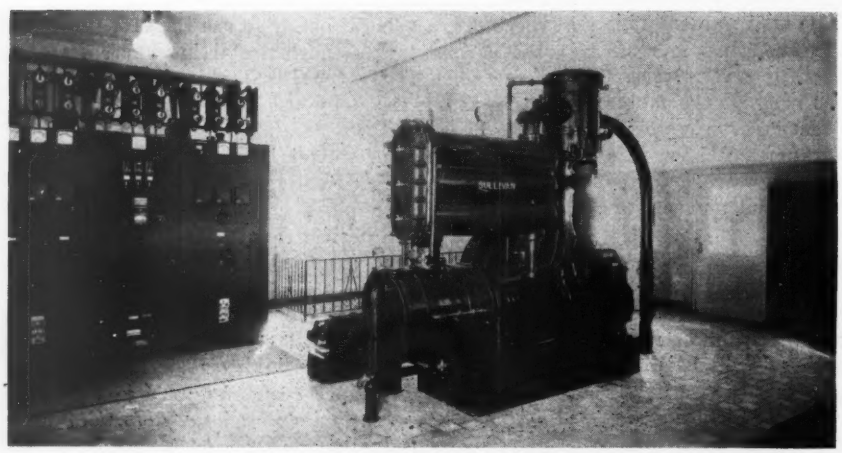


Fig. 2. Heavy duty compressor with direct connected synchronous motor and full voltage starter

in magnetizing these low power factor induction motors.

Only in a few cases will an .8 leading power factor motor be desirable because it has slightly higher losses than the unity power factor motor. A good general rule will be to figure the cost of this excess leading power factor current when produced by the synchronous motor against the cost if supplied from the power plant or by the power company. This can be readily done with a knowledge of the motor efficiencies at unity and .8 power factor and a consideration of the contract involved.

HIGH SPEED SYNCHRONOUS MOTOR: The high speed synchronous motor has about the same starting characteristics as a squirrel cage induction motor of the normal torque normal starting current type. In sizes above about 7½ hp. this motor must be started by means of a reduced voltage starter to avoid excessive inrush current. Designed originally for general use it has the 15 per cent, or general purpose, reserve factor.

The high speed synchronous motor can be used instead of either the squirrel cage induction motor or the slip ring motor or belt driving slow speed compressors, or for direct connection to high speed compressors, but because of the fact that this motor costs more than either of the other two types of motors, it will be applied only when power factor consideration makes justifies the higher first cost. If power factor considerations dictate the use of a synchronous motor, consider the space saving with the slow speed motor before deciding which type.

SLOW SPEED SYNCHRONOUS MOTORS: The slow speed synchronous motor has become the standard drive for large heavy duty compressors in industrial plants, primary air supply plants at mines, and on construction projects where compressors will be installed in a given location for a period of two or three years. This motor is generally of the engine type, that is, furnished without shaft or bearings for mounting directly on the compressor shaft. This motor is generally given its maximum rating, the given frame size of motor being rated at a certain horsepower, 50 deg. C. rise.

The slow speed synchronous motor has desirable torque and starting current characteristics, starting current ranging between 250 and 400 per cent of full load current, with 40 per cent starting, 40 per cent pull-in and 150 per cent maximum torques. At first thought it might seem that the 40 per cent starting torque, 40 per cent pull-in torque would be somewhat low, but since these large slow speed compressors are usually completely unloaded during the starting period, 40 per cent of full load torque will be ample to overcome friction at break-away and to accelerate the unit to full speed.

Although the starting current on these motors is quite low, there are a few cases where reduced voltage starters are desirable. This will only be when the motors are used in municipalities having very rigid power supply regulations, or in localities where the transformers or transmission lines are not capable of carrying any great amount of current above the normal running current of the motor.

The slow speed synchronous motor is generally applied to compressors going into locations where they will be used for a period of years. The high efficiency obtainable with this type of drive, the desirable power factor characteristics, low space requirements, make it a very satisfactory drive for industrial compressors, machines installed in processing plants, public utilities, and as a primary source of air at mines.

Fig. 3. Mineair compressor with built-in direct current motor, magnetic reduced voltage starter, circuit breaker and disconnect plug

DIRECT CURRENT MOTORS

The direct current motor is generally used only for small mine car compressors or in locations where direct current is the only power available. Because of the fact that most power systems are now alternating current systems it would be necessary to use conversion equipment to obtain direct current and the loss in the conversion apparatus would make power consumption in terms of the primary alternating current supply excessive for a direct current motor drive.

The direct current motor must be started on reduced voltage, since at low speed, the motor has very little counter E.M.F. and the inrush current would be excessive if the motor was thrown directly across the line. Because of the variation in voltage in mines and on street car systems, it is frequently necessary to supply a special motor for operation on a wide range of voltage. For example, the 500-v., d.c. motor for compressor drive may be so wound that it will operate successfully on a voltage which varies between 400 and 600 v.

Direct current motors are usually started by means of a rheostat type starter, either of the manual type which consists of a lever, or of a magnetic type which consists of contactor which cuts out the resistance as the motor is brought up to speed. It is generally recommended that a magnetic type of starter with some definite time acceleration be used for all direct current motors used for compressor drive. This is because of the fact that the motor starts up with very

little load, and if the operator throws the handle from the start to the full-on position rapidly the inrush current builds up to such values that it may damage the motor commutator. On the other hand, if the operator brings the machine up to speed very slowly the resistor itself gets very hot, and sooner or later causes trouble. The magnetic starter with definite time acceleration brings the motor up to speed in the period of time which gives the best motor commutation without overheating the resistor.

Starting Current Characteristics

It will be noted that on all A.C. motors the starting or inrush current is limited only by the reaction of the motor. It is therefore absurd to state that the starting current required by one compressor may be higher than the starting current required by another compressor, unless the two units are using different sizes or different types of motors or starting equipment. The starting kv-a., which is the current in amperes times the voltage, also depends on the type of motor. Starting kv-a. multiplied by the power factor during the starting period and multiplied again by the time required to accelerate the compressor, gives the actual power used during the starting period. Due to the fact that only a few seconds are required to accelerate any of the standard types of compressors, this starting power in kilowatts will usually be a very small percentage of the total power used, except for compressors that are arranged to start and stop rather than to operate continuously, loading and unloading. The power in kilowatts required to accelerate a compressor will depend on the amount of flywheel effect, but will also depend, perhaps to an even greater extent, on the degree of unloading. If the compressor is fully and completely unloaded power will be required only to overcome friction and to accelerate the rotating parts of the machine.

Note: This is the first of two articles on the subject of air compressor drives by Mr. Bartholomew. The second discussing the question of motor control equipment will appear in a subsequent article.

High Pressure Steam Utilization

In a recent issue of the "Zeitschrift des Vereines Deutscher Ingenieure" some details are given of the progress of the utilization of high-pressure steam in electric power stations in Germany. It shows that at the middle of last year there were 51 such boilers with a total production capacity of 2115 t. per hr. in use in that country, this corresponding to 24 turbines working with steam at a pressure of over 1422 lb. per sq. in. and running at 3000 r.p.m. The same article states that in August, 1936, there were in use throughout the world 15 land and 9 marine Benson high-pressure boilers; of the La Mont type, 76 land and 74 marine boilers as also two locomotives—this system has also been applied to 114 other boilers—of the Loeffler type 22 land and one marine boiler; also one locomotive; of the Sulzer type, 14 land and one marine boiler; of Schmidt type, 23 land, 2 marine and 5 locomotive boilers; and of the Velox type 35 land, one marine and one locomotive boiler.

Smoke Eliminated by Super-Sound Wave

SUPER-SOUND waves are employed in a device invented by H. W. St. Clair, metallurgist, U. S. Bureau of Mines, to solve the smelter-fume problem, and should also be of value in helping to curb the smoke nuisance in large cities.

It has long been known that, when sound waves are passing through a tube containing a fine powder, the powder will be concentrated at points that are free from vibratory motion. It has also been known that waves of extremely high frequency affected the diffusion of solid or liquid particles in a gas. As the Bureau of Mines points out, however, no practical application has previously been made of this knowledge.

The St. Clair method merely passes the smoke or fume through a tube in which standing sound waves are established. These standing waves are produced by so adjusting the length of the tube that waves reflected from the upper end are in phase with the original sound waves set up at the lower end.

In order that the process may work at its best, the wave-length used must be approximately equal to the diameter of the tube. For a tube of practicable diameter, this means that the frequencies used will vary from 3 to 20 kilocycles per second. A person of acute hearing can detect waves of frequencies up to about 5 kilocycles; those of greater frequency are above the auditory range and hence are sometimes called "supersonic."

To generate sound waves of this frequency, several types of equipment may be used. Mr. St. Clair has used what is technically known as the magnetostrictive method, but for purposes of popular demonstration, an acoustic generator is used. This, in fact, is merely a shrill whistle. The sound waves produced by the whistle are reflected in phase with the original waves from the top of the tube and cause the solid particles to fall out of the gas stream. The action is similar to the effect produced by drawing the bow of a violin over a metal plate on which dust particles are deposited, when the vibrations cause the particles to arrange themselves in groups.

The Bureau of Mines for many years past has been interested in the problem of smelter fumes. As long ago as 1929 it began work on the possibility of settling smoke by means of acoustic waves.

The installation of the process that has now been devised should be comparatively inexpensive, as it utilizes simple sound waves instead of the more elaborate processes employed in other fume-treatment methods, and is therefore adaptable to the smaller plants.

Patents covering the new process will be applied for by members of the staff of the Bureau of Mines for the benefit of the public.

The process was demonstrated at the annual meeting of the American Institute of Mining and Metallurgical Engineers in New York, the demonstration in Washington being a preview for officials of the Department of the Interior.

SAFETY In Elevator Operation

Pertinent information on the operation and maintenance of electric elevators

By C. C. CUSTER

ELECTRIC ELEVATORS have taken a prominent place in our modern civilization as a means of making vertical travel safe. The necessity for passenger and freight elevators is evident from the fact that without them buildings of three or more stories would be inconvenient for habitation or other use and the modern skyscraper office building would be impossible.

Among other duties, the chief engineer of any modern factory, office, or apartment building is responsible for continuity of service, safety of service, and efficiency of service of a number of passenger and freight elevators.

One of the ear-marks of a first class engineer is the possession of a considerable fund of knowledge on many of the subjects relating to his trade. What the busy world seems to want more than anything else is men who are capable of rising to the occasion and stepping into the breach in times of emergency, who are prepared with the proper information at their finger-ends, who do not have to hunt for an alibi, but are Johnny-on-the-spot, and know how to do things and get things done. It is not enough to be an experienced engineer but one should be able to capitalize the experiences of others, which can be done by making a study of standard practices. Obviously an engineer should not only be able and organized to take care of emergency repairs but should also be well versed in the standard practice routine which is effective in keeping accidents down to a minimum.

The object of this article is merely to point out for the benefit of the operating engineer just what things are considered necessary and proven by experience to be needful for the fullest measure of success in the operation and maintenance of his elevator equipment.

Qualifications for Elevator Engineer

In the first place the engineer should know his elevator and keep a log book with all the more important data of his machine. The engineer should know something about the trend of modern elevator design. He should know what types of elevators are obsolete and know their weak points. He should have a vision of the hazards surrounding elevator operation and how accidents occur so he can take precautionary measures to prevent them. He should know what is proper maintenance and repair of elevators. He should know the proper rules of routine for the safe operation of elevators. If the engineer's knowledge in general of the functioning of elevators is faulty, he ought to get some good text book on the subject. His library should also contain "The A.S.M.E. Code on Electric Elevators." If he can master this book he will at least know what is standard design.

There are three different functions connected with the operation of an elevator: Inspection, servicing, and operating routine. If the elevator is insured, there will be insurance inspections periodically, at which time it will be advisable that the engineer accompany the insurance inspector on his trip; but at in-between periods there ought also to be inspections made by the engineer. The servicing of an elevator refers to the periodic attention necessary to keep the bearings, guides and other working parts oiled and cleaned. This kind of service is often furnished by outside parties who make periodic visits for a fixed charge per month. In the operating routine is the proper selection and training of elevator operators.

The law requires, in many states, that elevator operators be of adult age and have some preliminary training. Besides carefully leveling the car at the landings they should keep their eye on the passengers being carried; see that they stand well back from entrance and watch their step when getting on and off. The elevator operator should have enough experience in the operation of the car to know when it is operating properly so when anything unusual occurs he can promptly report it to the engineer for investigation. For instance, I remember once getting on a car to inspect it and immediately noted that it stopped with a sudden jerk; the operator had not as yet seen fit to report it. On going to the penthouse we found the brake-shoes hot and smoking, having been adjusted too tight so that they grabbed, throwing an usual strain on the cables when stopping the car.

Elevator Accidents

As to getting a vision of how accidents occur, we may profitably study a few statistics gathered in the city of Chicago some years ago. Of 401 elevator fatalities reported to the Coroner of Cook County over a period of 12 yr. the causes were tabulated as follows:

	Per Cent
Falling elevators	6.0
Falling down shaftway	42.2
Crushed between car and sill	37.9
Struck by elevator	5.7
Struck by counterweights	2.8
Crushed in elevator	2.0
Struck by falling objects other than elevator	1.9
Crushed by machinery of elevator	1.0
Unknown causes	.5
	100.0

Ordinarily timid individuals upon entering an elevator sense as the greatest danger the possibility of the cables breaking and letting the elevator fall. In the cases covered by the above table, however, this type of accident was responsible for only 6 per cent of the fatalities, hence it was only a moderate hazard, by periodic inspection of the car cables their condition can be checked so that they can be renewed before there is any particular hazard in that direction.

The greatest hazard is apparently not the elevator itself but the hoistway, as we find that 42 per cent of the fatalities were caused by falling down shaftways that were evidently not properly protected; and the second greatest hazard was involvement in the doorways and getting crushed between car and sill, which was responsible for 37 per cent of the deaths. All causes other than these two were comparatively unimportant. Both of these two greatest hazards can be almost entirely eliminated by the use of proper gates or doors and by interlocking the movement of the car with the opening and the locking of the door. This is done by the use of interlocks which prevent the operation of the car when the gate is open and prevent the opening of the gate from without the shaftway unless the car is at that landing. Elevator interlocks may be classified as electric, mechanical, and electro-mechanical interlocks, depending on whether the results be accomplished electrically, mechanically, or by a combination of the two. Each of these three types of interlocks has its advantages and disadvantages. Any one of them would probably remove the hazard of an open shaftway if properly maintained in working order. It is thus up to the engineer in charge to see that interlocks that do not function are immediately reported and promptly repaired.

Assuming Charge of Elevators

If I were to take charge of the operation of a large installation of elevators, I would first want to gather together all the available information in regard to the installation. This would include catalog and instruction books of the makers, consulting the office files in reference to all correspondence concerning the equipment as well as all accidents of record and troubles experienced. I would want to make an invoice of all supplies and repair parts on hand so I would not be caught napping if some sudden emergency repair were necessary.

I would next want to make a thorough inspection of each elevator to determine its physical condition, following some sort of routine such as followed by an insurance inspector. I would want to get a wiring diagram for the switchboard and interlock connections and have it framed and hung in the penthouse, so it would be available in case I would have to trace out any of the electrical connections. As generally all the hoistway gate and other interlocks are wired in series, I might have at any time occasion to chase out open circuits. I would also want to investigate the switchboard and find out which were the "up" magnets and which were the "down" magnets, for the reason that at any time I might have the occasion arise that I would have to inch the car off its lower limit stops in case the car should overrun and slip through its brake. Wherever there are any fused circuits, I would want spare fuses near for emergency use. In fact, a little preparation and forethought will enable the engineer in charge to take care of all emergencies and minor adjustments without calling for outside help from elevator service companies other than for such major repairs as installing new cables.

One of the important duties of the operating engineer is keeping track of the condition of the elevator cables. This subject the writer has covered in an article of some length in the issue of Power Plant Engineering of date May 15, 1932.

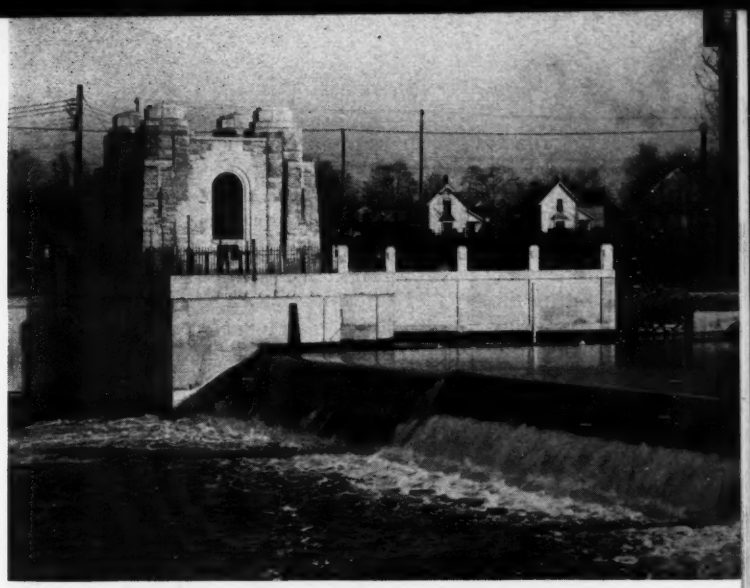
For further edification of those interested in the elimination of elevator accidents we expect to treat of "Typical Elevator Accidents" in a future issue of this magazine. This will be a presentation of a list of typical accidents that are found to be "repeaters" and if the operating engineer has a vision of how these accidents come about the problem of avoiding them is generally a simple one.

Routine of Elevator Inspection

1. (A). Report to owner or manager of building.
   (B). Get some one to go along to help, if possible.
   (C). Get the data if it is a data inspection.
2. Visit the machine room to see type of machine, foundations, etc. Inspect for (a) Lubrication, (b) Signs of wear, (c) Looseness of nuts, lock-nuts, bolts, cotter-pins, keys, pulleys on shaft, (d) Soundness of cast-iron parts, such as drums, arms, hubs, and pulleys; sound tests, (e) Arrangement and equipment of penthouse, (f) Condition of machine brake, (g) Machine limit stop, (h) Cleanliness of machinery from a fire standpoint, (i) Condition of switchboard contacts, potential switch, directional switches, pull-in or accelerating magnets, (j) Speed governors and other safety devices.
3. Inspect cables,—for the following:
   (a) Rusting, (b) Crown wear, (c) Broken wires per strand, (d) Condition of grooves, (e) Size of sheaves, (f) Reverse bending, (g) Where greatest wear is found, (h) Condition of cable ends, tension, chafing of cables, (i) Amount of stretching of cables, (j) Tension of a pair or set.
4. Observe condition of hoist way as observed from top of car:
   (a) Shear plates below door landings, (b) Counter-weight runways, (c) Condition of guides, (d) and how they are secured, (e) Fuzz on guides, (f) Inspection of cables from the shaft way, (h) Slow, down and final limit switches, (h) Switch-boxes and cams, (i) Retiring cams, (j) Car-beam shackles, (k) Equalizing devices, if any, (1) Shaft way and car door interlocks and contacts.
5. Inspect interior of car and safety devices:
   (a) Controller, (b) Shipper cable, (c) Annunciator, (d) Emergency stop switch, (e) Condition of enclosure, (f) Clearance in shaft way, (g) If an automatic elevator, see if it lands properly at sills, (h) If a shipper-cable control, see if stop buttons are properly set, and whether there is a cable lock, (i) Condition of car floor.
6. Inspect under-car parts:
   (a) Soundness of beams and flooring, (b) Loose nuts or slackness in bolts, (c) Cut-out switches, if any, (d) Floor levelers, if any, (e) Testing limit switch, (f) Fit of car-guide shoes, (g) Fit of safety guide shoes, (h) Condition of roller grip or knurled nut instantaneous safeties or any other kind of safeties to keep the car from falling, (i) Condition of drum and clamp type of safety and whether they will function, (j) Whether the safety operating cable is properly wound.
7. Inspect pit:
   (a) Proper depth, (b) Drainage, (c) Counter-weight runways, (d) Clearance below car, (d) Clearance below counter-weights, (e) Buffers in pit and their condition, (f) Trash in pit, (g) Water in pit.
8. Determine whether the car operators are of lawful age and well trained:
   (a) Instruct how to look out for their passengers, (b) List what things should be reported.
9. Finally report to owner of building, or chief engineer.

Automatic Hydro Plant

Lansing, Mich., adds North Lansing automatic hydro-electric station to system. Movable crest dam with automatically operated drum gates maintains constant pond level.



Architecturally and mechanically the plant is an asset to the city The dam was built primarily to maintain constant river level through the city and provide a pond for a new steam plant. Power is incidental

PERFECTION of automatic control has done much of recent years to make the development of small water power sites economical. A plant of this kind recently completed by the Board of Water and Electric Light Commissioners of the city of Lansing, Mich., is expected to produce over 1,000,000 kw. hr. per yr. from a single 200 kw. unit operating under an 8 ft. head. Development of power at the damsite is, however, incidental, as the dam was built primarily for the purpose of maintaining a constant water level in the Grand River through the major portion of the city, and to provide a pond for a steam electric generating station on which construction will begin this summer.

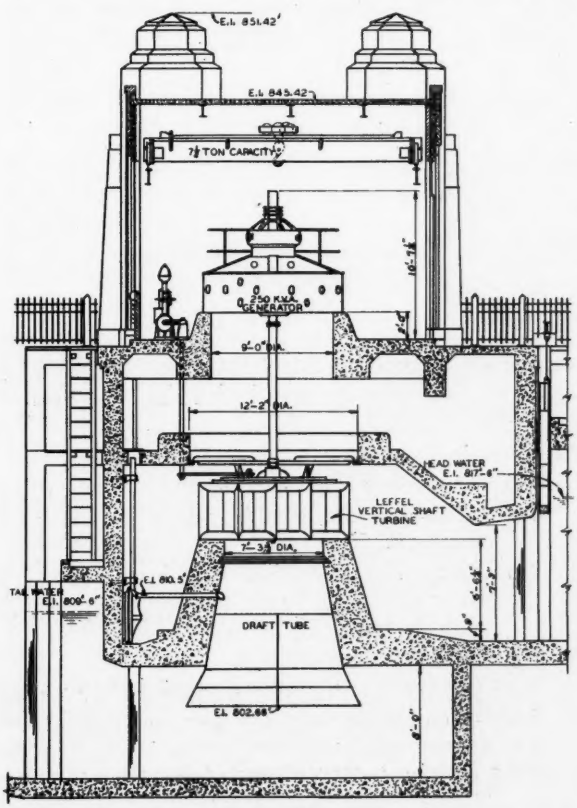


Fig. 1. Cross section of the plant which contains one 200 kw. unit which it is estimated will turn over 1,000,000 kw. hr. per yr.

The plant itself is within the city limits and the water rights were purchased by the city from a nearby flour mill. The new dam, which replaced the original rock filled timber crib dam dating back to 1838, is concrete, 233 ft. 4 in. long with movable crest made up of four drum type gates. Each gate has a discharge capacity of 1250 c.f.s. without change of pond level and the entire dam has a capacity of 25,000 c.f.s. without flooding the banks. Flood records show that a flow of 5000 c.f.s. has been exceeded but 31 days in the last 15 yr. The highest recorded was 24,000 c.f.s. in March, 1904.

As shown by the cross section, the dam rests on the stream bed and is sealed off by three rows of steel sheet piling driven to rock at elevation 797, approximately 9 ft. lower. On the downstream side is an 18 ft. apron to prevent scour of the stream bed. A 3½ ft. inspection gallery runs the full length of the dam on the upstream side and a smaller drainage and service duct on the downstream side. Six fiber conduits have been incorporated in the base in case future needs call for their use. Danger of freezing, which has limited the use of this type of gate in cold countries, is guarded against by electric heaters incorporated in the metal conduits shown. One conduit circles each face of the pier at the end of each gate while another runs the length of the lip seal.

Details of these seals, one upstream at the hinge and the other downstream at the skin plate are shown by the insert on Fig. 2. The seal is made up of a special seal rubber held in place by a backing block and adjusting bolt, the entire assembly being protected by a removable cover. The front of the gate is a flat plate, and the back an arc bent on a 4 ft. 7½ in. radius, the center of the circle forming the pivot point for the gate. The upper part of the gate is sealed off, to form a buoyant chamber and strengthened by guards at frequent intervals. The gates are completely welded, and made by the Lakeside Bridge & Iron Works to close specifications. Tolerances were 1/16 in. plus or minus on the radius and 1/16 in. plus or minus on any 15 ft. cylindrical chord.

Head water pressure is introduced into the chamber under the gate and the moments are so calculated that as the water breaks over the crest of the dam, the gate will sink sufficiently to maintain the pond level constant. By controlling the pressure under the gates the crest may be set at any desired level between the operating limits of 813 ft. 6 in. and 817 ft. 6 in. This control is by means of Chapman inverted sluice gates in a control well adjacent to the power house.

The water wheel is a fixed blade, high speed Leffel 54 in. Type B4 with low carbon steel buckets, semi-steel gates and a conical steel draft tube. It is of the design tested and rated by Holyoke Test No. 3106. Under a net head of 8 ft. and at 120 r.p.m. it is rated at 300 hp., the output at other heads ranging from 6 to 8.5 ft. Are as shown by Fig. 4. Under the maximum head of 8.5 ft. the runaway speed is 236 r.p.m. and the total thrust load, including the runner and shaft and generator rotor, is 35,000 lb. The governor is a Woodward Type HR oil pressure type with a rating of 6,700 ft. lb.

This turbine drives a General Electric Type ATI-W, 60 pole, 120 r.p.m., 250 kv-a., 0.8 p.f., 480 v., 3 ph. 60 cycle generator and 12 kw., 125-v. shunt wound direct connected exciter. The WR^2 effect of the rotor is 85,000 ft. sq. lb. Six resistance temperature detector coils are embedded in the stator winding and amortisseur windings are provided to increase the synchronizing capacity of the generator and prevent excessive shock when the unit is thrown on the line by the automatic equipment. Four metallic asbestos blocks, hydraulically operated, act on the lower side of the rotor, to bring the unit to a stop when the gates are closed. The generator rotor, runner and thrust are carried on a spring type bearing.

Operation is controlled by a G.E. float switch which starts the unit automatically when the pond level reaches 817 ft. 6 in., the crest level, and stops the unit after a draw down of 9 in. The float switch energizes a solenoid valve to admit oil pressure to the governor, which opens to about 1/3 gate immediately and gradually opens up so as to bring the unit up to speed slowly. At about 98 per cent synchronous speed a centrifugal switch on the generator closes to operate the main oil circuit breaker and put the unit on the line operating as an induction motor. The field circuit is then closed and the unit pulled into synchronism. Control power is obtained from the exciter bus and from a transformer connected to the line side of the circuit breaker so as to provide control power before the exciter is up to speed. Details of the automatic starting circuit and sequence of operation are shown by Fig. 4.

The entire control equipment, included in three cubicles, was supplied by General Electric Co. In addition to the necessary watthour meters and operating instruments there is a recording ammeter and counters which record the number of starts and stops and the total time in hours that the unit operates The generator room is served by a 7½ t. Shaw-Box crane.

In addition to the regular starting and stopping sequence the automatic control equipment provides the following (numbers in parenthesis refer to equipment as marked on Fig. 4):

1. Prevents starting the machine if—
   (a) The a.c. line is not energized (4).
   (b) It has been shut down by a lock out protective device (35, 51 or 40).
   (c) Until normal conditions have been restored if it has been shut down temporarily by an a.c. thermal relay (49) or with low oil pressure (63).
2. Prevents the opening of the generator oil circuit breaker on normal shut down, or on transient low a.c. voltage until the wheel gates are in running light position (nearly closed) (33A).
3. Prevents the generator being reconnected with the line without going through the normal sequence of

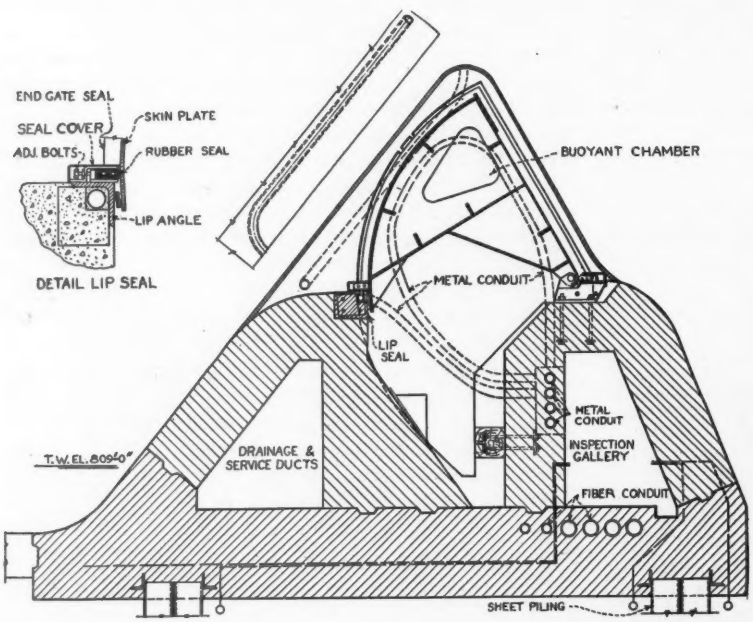


Fig. 2. Section through the dam and gates. The gates are buoyant and so balanced that they drop automatically as the water flows over them so as to maintain a constant pond level

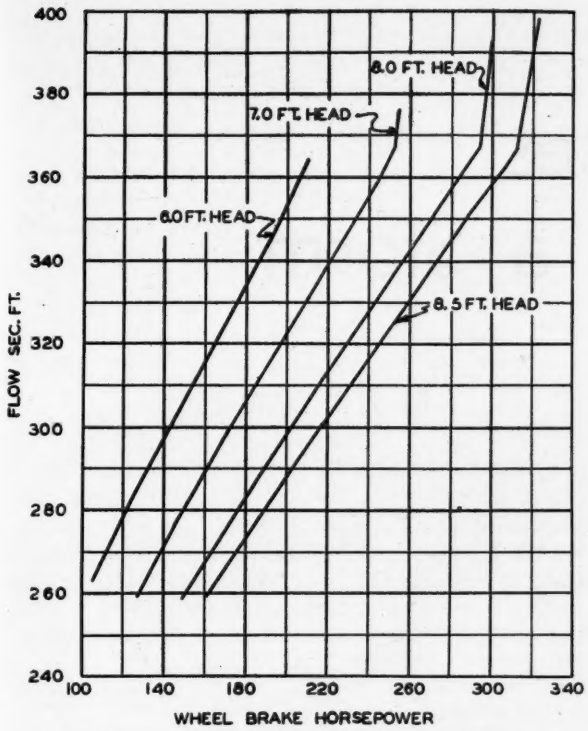


Fig. 3. Guaranteed performance of the water wheel

starting (13X) in case the generator breaker (52) has opened for any reason.

4. Protects against exciter overvoltage (45) by inserting extra resistance in exciter shunt field circuit.

5. Shuts down the machine when the stopping indication is given by control element (1) or (1M).

6. Shuts down the machine temporarily and restarts if the proper starting conditions have been reestablished.
   (a) The machine tends to overspeed and restart when the speed is reduced to about 80 per cent of normal value (12).
   (b) The machine is subject to moderate overload which tends to overheat the generator (49).
   (c) The machine is subjected to operation on single or badly unbalanced phases sufficient, if continued, to overheat the generator (46).
   (d) The oil pressure for operating the governor should fall below a safe operating value (63).
   (e) The a.c. voltage should tend to be excessive (59).

7. Shuts down and "locks out" the machine if:
   (a) A bearing should overheat (35).
   (b) The excitation of the generator should fail but not to shut down by a transient fluctuation in the field current (40 and 86).
   (c) The generator is subjected to harmful overload or short circuit sufficient to require inspection, adjustment or repair before being placed in service again (51 and 86).

On August 8, 1936, acceptance tests were run on the unit at full and 0.7 gate opening. Water was measured by two calibrated current meters traversing the rectangular uptake flume. Heads were measured by gage rods inside and outside the trash racks and in the tail race. Head loss through the trash rack ranged from 0.12 to 0.18 ft. and the tail water increased 0.65 ft. over flow range of 286 to 368 sec. ft. covered by the test. The net head (including correction for velocity head at the outlet of the draft tube) was used in calculating the results. Power used by the exciter was added to the main generator output when figuring efficiencies. Generator guarantees were for ¼, ½, ¾ and full load; 78.7; 85.6; 87.5; and 87.6 per cent respectively. Factory tests were 83.8; 89.9; 90.5 and 90 per cent for the same loads. Test results, as shown by the accompanying table for two loads, materially bettered guaranteed efficiencies. In calculating the wheel efficiencies, shop tests of the generator were used.

Results of Test on North Lansing Hydro Station:

Gate opening	Full	0.7 Full
Head ft.	7.24	7.00
Kilowatt load	176.4	103.0
Actual overall efficiency, %	80.6	63.8
Guaranteed overall efficiency, %	74.3	59.0
Margin better than guarantee, %	+6.3	+4.8
Actual turbine efficiency, %	89.2	70.9
Guaranteed turbine efficiency, %	84.8	68.8
Margin better than guarantee, %	+4.4	+2.1
Factory test generator efficiency, %	90.4	90.0
Guaranteed generator efficiency, %	87.6	85.8
Margin better than guarantee, %	+2.8	+4.2

The plant was designed by the Engineering Department of the Board of Water & Electric Light Commission under the direction of O. E. Eckert, general manager and C. R. Erickson, mechanical engineer.

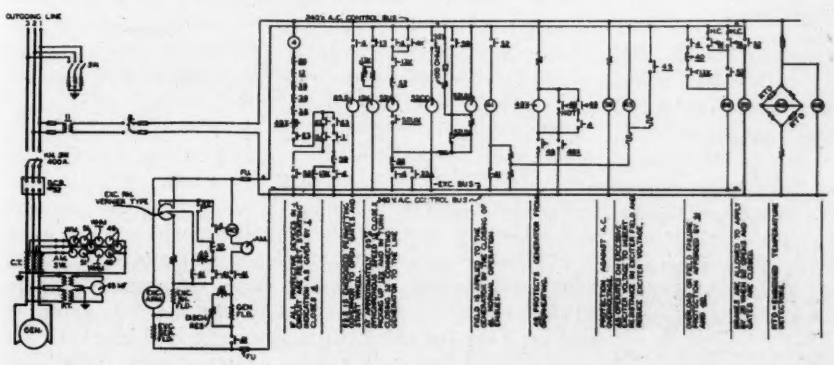


Fig. 4. Diagram of the automatic starting equipment. (Devise Numbers are NEMA standard)

Flue Gas Analyses Blow up a Storm

Controversies over the relative merits of CO_2 recorders and boiler meters as operating aids emphasize the importance of considering fuels as well as flue gases

By J. R. DARNELL*

UNDER the title of "The CO_2 Recorder," an article by Henry Cooney in the April (1936) issue, page 249, extolled the virtues of this device and then explained how the recorder readings could be checked by an Orsat. A table showed excess air values corresponding to given CO_2 and O_2 values. The author formed the conclusion that natural gas may be burned most economically when the CO_2 value as indicated by the recorder is kept as near the ultimate as possible, but warned against the use of formulas to calculate the excess air by the use of CO_2 values, taken from the recorder, without considering the amount of oxygen and carbon monoxide present.

On page 369 of the June issue, Ralph R. Swain disagreed with Mr. Cooney regarding the practical operation of furnaces with theoretical combustion conditions. He said he had never found a case where CO was not present when the excess air was as low as 10 per cent. Mr. Swain further stated that CO_2 measurement alone, without knowing the excess air, was not a good combustion guide because experience with the Orsat showed flue gas samples varying as much as 2 per cent in CO_2 with no change in excess air. He said this was due to changing analyses of the fuel gas. Mr. Swain disagreed with the statement that modern furnaces will withstand the heat of the perfect combustion of natural gas, pointing out that this would be true with water cooled furnaces but if refractories were used they would need to be of exceptional quality. Water cooled walls, on the other hand, retard combustion of gaseous fuels at low ratings.

CO Present Must Be Considered

In rebuttal, page 549 of the September issue, Mr. Cooney takes issue with Mr. Swain's statement about the futility of reliance on CO_2 measurement instead of excess air as a combustion guide and in support of his argument refers to equations, given in a publication of the American Gas Association, for calculating excess air from the CO_2 percentage. Mr. Cooney, however, admits that such calculations must presuppose complete combustion with no CO present. This, I believe, is the crux of the problem. Twenty years' experience with a wide variety of solid, liquid and gaseous fuels has shown that although Mr. Cooney is partially correct in his statements regarding combustion calculations, the question of economical operation at or near perfect combustion is debatable. Such operation is, beyond doubt, the most efficient, but it may be far from economical if refractory maintenance is excessive or, if when water cooled walls are used, combustion is retarded at low ratings.

Since Mr. Cooney has given us the values of 86 per cent methane and 14 per cent ethane as representing the analysis of the natural gas used as fuel and these values are assumed to be on the volumetric basis, calculation shows that the theoretical furnace temperature will be about 3650 deg. F., when the gas is burned with no excess air. The actual furnace temperature may be a few hundred degrees less but any temperature over 3000 deg. F. is more than most refractories can withstand and severe slagging will occur unless carborundum is used. Air cooling, of course, will help but has not been found to be a satisfactory means of protecting walls and usually is subject to considerable leakage.

Natural gas of the above analysis has about 21,300 B.t.u. per lb. as compared to 18,500 B.t.u. for fuel oil or 11,500 B.t.u. for mid-western coal. It can readily be seen therefore that a fuel of such high heat value will develop an excessive furnace temperature if burned with no excess air even though it may be possible to have such intimate mixing of air and fuel that complete combustion is effected at all times.

Also there is a statement in Mr. Cooney's reply which is inconsistent with everything preceding. He says: "If the meter is set empirically at 19 per cent for natural gas, as suggested by one investigator in this field, the error may assume considerable proportions in some installation, since, according to this same authority, this is not the best percentage obtainable but a normal every day average." In his April article he told us his theoretical CO_2 was 12 per cent and then in this September issue he says the maximum CO_2 value for natural gas would not vary more than 0.5 per cent with changes in analyses. Therefore, why does he even consider the possibility of 19 per cent and say that in such assumption "the error may assume considerable proportions?" A maximum theoretical CO_2 value of 19 per cent for natural gas is simply unthinkable. As a matter of fact only the lower grade solid fuels have

*Consulting Engineer, Jenkins Petroleum Process Co. and Donnelly Process Corp.

19 per cent or over. Gaseous fuels (except blast furnace gas, which has considerable CO_2 in the raw gas) generally have values under 14 per cent.

Theoretically Maximum CO_2

The following table shows the average theoretical maximum CO_2 for various representative fuels, assuming complete combustion:

Wood	20.3 per cent
Rice anthracite coal	20.0 per cent
Lignite	19.0 per cent
Bituminous coal	18.6 per cent
Fuel oil	15.2 per cent
Refinery gas	13.2 per cent
Natural gas	11.8 per cent
By product coke oven gas	9.3 per cent

Mr. Cooney has another questionable statement:

"The greatest source of error in the steam flow-air flow meter arises from the presence of moisture or inert gases in the fuel, or when steam is used over the fire. These inert vapors produce a record on the air flow but are not effective in making steam."

Water vapor in the products of combustion, whether present originally as moisture in the fuel, added later for various reasons, or formed by the process of combustion, does not separate from the CO_2, O_2, or N_2 in the flue gases (unless chilled below the dew point), but is an integral part of the flue gas and as such is measured by the so-called "air" portion of the boiler meter. Designers of these meters take this water vapor into consideration when given complete information. It might happen, however, that a meter installed and calibrated for oil firing with mechanical atomization would be in error if steam atomization were used, as the latter condition would add from ⅓ to ¾ lb. of water vapor to the products of combustion per pound of oil burned, for any and all percentages of excess air. For example, if with mechanical atomization, when operating with 25 per cent excess air, there were produced 18 lb. of flue gas per lb. of oil burned, steam atomization would increase this weight to about 18.5 lb., which would make a slight error in the meter. But if told before hand the manufacturer could adjust for this condition.

It is true that additional water vapor will reduce the furnace temperature and also increase stack losses, but on the other hand, since the weight of gases is increased, the mass velocity will be increased and this will partially offset the reduction in temperature, as a factor in steam production.

Air Flow Measurement

The so-called "air" flow indicator of the steam-air flow meter is operated by the draft pressure differential between two points in the boiler setting, usually between the top of the first pass and the uptake. An increase in the rate of flow of the products of combustion produces a greater pressure difference, which acts on the air flow pen mechanism. But this pen will show the same reading as the steam flow as long as the desired relation exists between the air used for combustion and the steam output. In other words, the amount of excess air used is recorded in terms of the amount of products of combustion produced.

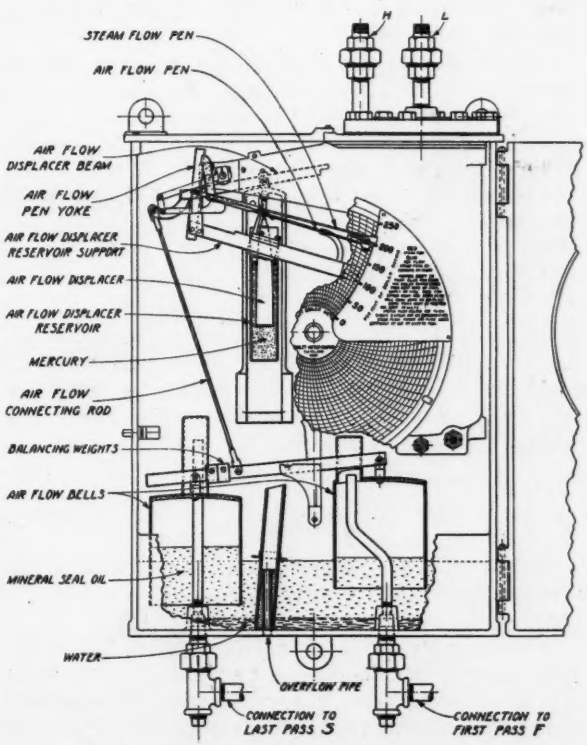
As shown in the accompanying figure, the two connections "S" and "F" at the bottom of the instrument casing are connected to the uptake and the top of the first pass respectively so as to cause the draft pressure at each of these points in the setting to act on the two air flow bells. The difference between these two pressures produces a force which lifts the air flow displacer out of the mercury. This movement is translated to an adjustable beam, which governs the travel of the air flow pen.

It has been my experience that this boiler meter is more reliable and of greater assistance to the operator than any CO_2 recorder.

I agree with Mr. Cooney that Mr. Swain should seek causes other than variations in fuel analyses to account for variations in CO_2 with the same amount of excess air. The explanation probably lies in the formation of CO and this could readily be determined, even without an actual measurement of this gas in an Orsat if the CO_2 and O_2 are accurately measured with no unburned gases in the sample.

Checking Flue-Gas Analyses

In the April 1926 issue of Mechanical Engineering, Vol. 48, pp. 328-336, A. A. Bato offered the most ingenious method for checking flue-gas analyses and computing the results I have ever seen. By means of Mr. Bato's equations it is not necessary to have an ulti-



Working mechanism of steam flow—air flow meter

mate analysis of the fuel to determine the maximum CO_2, the oxygen for lower values of CO_2 or percentage of excess air corresponding to any CO_2 value. Also the maximum CO_2 can be calculated for conditions where combustion of the carbon is incomplete but the hydrogen has been completely burned.

Equation 1 is to be used for calculations assuming complete combustion and No. 2 for conditions where

CO is present. Equation 3 gives values for excess air when the maximum CO_2 and actual CO_2 are known. From Bato's equation 1 I have derived equation 4 which may be used to check the Orsat for the amount of oxygen which should be found when the maximum and actual CO_2 values are known. Maximum CO_2 is M, actual CO_2 is k, CO is km, and per cent excess air is E:

$$M = \frac{21k}{21 - O_2} \qquad (1)$$

$$M = \frac{21\,(k + km)}{21 - O_2 + 0.395\,km} \qquad (2)$$

$$E = \frac{(M - k)\ 79}{k\ (100 - M)} \qquad (3)$$

$$O_2 = \frac{21\ (M - k)}{M} \qquad (4)$$

The values given in the table on page 250 of the April issue check approximately with these equations, but it does not seem probable that values of CO_2 and CO would be found in actual operation without any trace of oxygen being present. Of course artificial conditions could be created wherein the air supply would be adjusted to produce a reducing flame such as Mr. Cooney described, but this is seldom found in normal practice.

When operating at about 10 per cent CO_2, which corresponds to 18 per cent excess air, there may be times when 0.5 to 0.7 per cent CO is found. The flue-gas analysis will then read: 10 per cent CO_2, 2.82 per cent O_2 and 0.5 per cent CO. The value of 2.82 per cent O_2 was calculated from equation 5, which I developed from Bato's equation 2:

$$O_2 = (21 + 0.395\,km) - \frac{21\,(k + km)}{M} \qquad (5)$$

If the Orsat showed 10 per cent CO_2 and 2.5 per cent O_2 and then the operator lost the sample before he could determine the CO, he could calculate the latter very easily by the following equation which I have also derived from Bato's equation 2:

$$CO = \frac{21 - (O_2 + 21\,k/m)}{21/m - 0.395} \qquad (6)$$

Substituting the foregoing values of CO_2 and O_2 in this equation we find that the value of CO would be 0.74 per cent.

Checking Mr. Cooney's values on page 250 of the April issue we find that even if we use the value of 20.91 (the exact percentage of oxygen in the air) instead of 21 in the above equations, his values of CO are slightly in error when reported to the second decimal place, although I have always maintained that when using a water Orsat it is not possible to read values closer than the first decimal place. If closer readings are required a mercury Orsat with compensator should be used. United States Bureau of Mines Bulletin 42 by G. A. Burrell and F. M. Seibert, later revised by G. W. Jones and published as Bulletin 197, "Sampling and Examination of Mine Gases and Natural Gas," describes the use of a mercury Orsat.

Contamination of Drinking Water

Bacteria found breeding spot in service pump

By Julius Brodsky

TO LOCATE the cause of and eliminate the contamination of the drinking water supply of a large public building proved to be a difficult but interesting problem. It was recalled that some time previously the water supply in a large Chicago hotel had become contaminated, resulting in the death of several of its guests, and it was necessary to forestall the recurrence of such an event.

The fact that this incident occurred in a public building in which were located the offices and laboratories of the public health service, led to an imme-

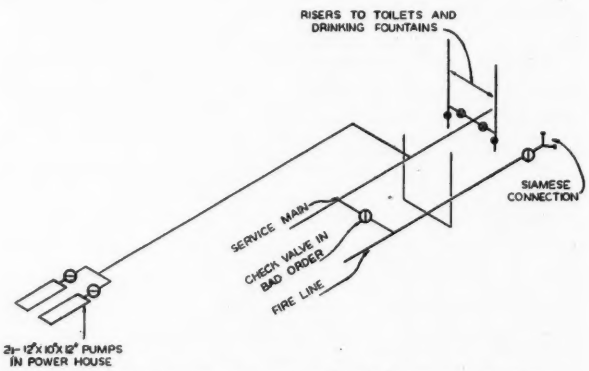


Fig. 1. Layout of service main and fire line in basement of building

diate detection and localization of the contamination and served to stop its spread thus avoiding disastrous consequences, although actual elimination of the cause was not accomplished till some time later.

City water pressure being too low for the buildings served, two 12 by 10 by 12 in. duplex pumps were used to boost the pressure, pumping directly into the service main under governor control. These pumps had recently been overhauled and all packing and soft rubber valves had been renewed.

When replacing the cylinder heads and valve chamber covers, new gaskets had been used which had been coated with a graphite and cylinder oil mixture.

The layout of the water main serving toilets and drinking fountains and its cross connection with the fire main was substantially as shown in the sketch Fig. 1; the siamese connection outside the building being provided for the purpose of allowing the local fire department to pump directly into the fire line.

A fire broke out in the upper floors of the building, which necessitated calling out the local fire depart-

ment which hooked onto the siamese connection to get the necessary supply.

No record had been made to indicate that this fire line had ever been in use or been tested to find out if it were serviceable. No sooner had the fire department connection been made than numerous leaks developed in the water system of the building and the booster pump in the power plant ceased to operate. It was immediately apparent that the check valve, installed between the house supply and the fire line for the purpose of preventing such a condition, was inoperative and the building system was being subjected to the full fire department pressure.

Fortunately it was the custom of the health department to take daily samples from the water system and examine them for evidence of bacteria. On the day after the fire, as the first sample taken showed positive evidence of the presence of bacteria, numerous samples were taken at various points in the system to determine its origin.

It was immediately apparent that since the fire line had not been used for some time, a considerable amount of dirt and foreign matter had collected in it and that whatever small amount of bacteria had been originally present in the water had multiplied to large proportions, and since the check valve between the fire line and service main was inoperative, all of this dirt with the bacteria present in it had been washed into the service main thus causing the contamination.

The system was flushed out and a chlorine compound used to sterilize it, and the pump in use at the time of the fire was taken out of service and the other pump put in operation.

Within a few days the situation cleared up and there was no further evidence of any contamination.

In the meantime the pump had been opened up and flushed out with hot water and steam; as soon, however, as an attempt was made to put it back in service the contamination appeared again. The use of this pump as an integral part of the water system was therefore forbidden until such time as it could be shown that all bacterial contamination had been eliminated.

The most desirable procedure of accomplishing this was to recirculate hot water through the pump while it was in operation. Accordingly an 8-in. ell and a piece of pipe about 6 ft. long were attached to the blank suction opening, the bottom of the check valve was drilled and tapped for a ¾-in. connection and a hose connected thereto which discharged back into the 8-in. pipe with the discharge and suction valves closed; a steam hose was also inserted into the 8-in. pipe to heat the water, which was kept as hot as it was possible for the pump to handle.

After thus washing out the pump it was treated with a chlorine compound, and the water tested at the discharge showed a negative bacteria content; after allowing the pump to stand a few days, however, and again taking a sample, the bacteria showed positive; this indicated a breeding spot in the pump.

Several attempts were made to eliminate the contamination by circulating solutions of soda ash, caustic soda and other proprietary compounds and after each attempt the pump was chlorinated; each time, however, the result was the same, negative bacteria immediately after washing and positive after the pump had stood a few days.

The health department men insisted that the bacteria was breeding in the packing, having found similar cases in water works; the offending plants, however, had used a hemp or flax packing whereas the packing in use was fibrous asbestos and cotton duck, and although the writer could give no definite reasons for not believing the packing at fault, he hesitated to remove it until all other remedies had been exhausted.

Recollecting the fact that when renewing the gaskets on the cylinder heads and valve chamber covers, a liberal coating of graphite and oil had been applied, it was quite possible that some of the oil had been squeezed out into the interior of the pump, it seemed probable that the bacteria was breeding in this oil coating, if any still existed.

Accordingly the pump was again opened up and scrubbed out with kerosene so that no trace of oil existed, it was then washed out with a caustic soda solution, flushed with clear water and treated with the chlorine compound.

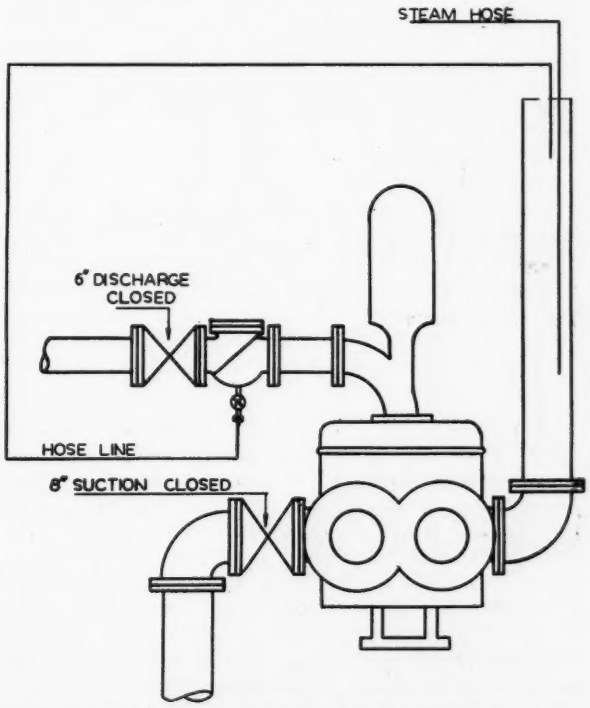


Fig. 2. Method of recirculating soda solution in order to cleanse pump

After this treatment no further evidence of bacteria was found and the supposition that the oil film left on the interior of the pump was the breeding ground for the bacteria proved to be correct.

This experience would indicate that it is essential that all oil, grease, dope, paint or other substances that might harbor bacteria, should be removed from the interior surfaces of a water system, where the water is intended for human consumption, and that the easiest way of doing so is by use of such easily obtained solvents as gasoline, kerosene or alcohol followed by flushing out with a soda solution to remove any residual taste or odor.

Controls Put New Life In Old Refrigerating Plants

By RAY B. WOLF

DURING RECENT YEARS all industries have made a concerted effort to modernize their plants and equipment, in order to lower operating costs to meet competition and combat rising costs. Recent building of new units with well planned layouts and automatic controls has set up new standards of operation and put the older plants with their manual control systems in an unfavorable position.

Many of the refrigeration plants built 5 to 10 yr. ago have met this challenge and have been able, with the recent developments of control devices and instruments and without too great an expenditure in money.

Engineering departments have their share to do in this work and can reduce operating costs of items under their control, such as the production and distribution of electric power and light, fuel, steam, water, air and refrigeration. The greatest saving and sometimes the quickest to effect in many plants in the food industry is by the lowering of electric power bills, as electric current is used in great quantities. In some localities, large users of power can at times make substantial savings by studying power schedules, picking the most favorable rate for the load conditions, not forgetting the generation of power when operating conditions warrant it. In some areas substantial discounts from the power bill can be enjoyed by correcting low power factor, and by a study of the incidental lighting load clause.

Installation of control devices of various kinds for certain services to eliminate manual operation often pays handsome dividends by lowering operating costs and improving the service. Some plants are particularly well adapted for automatic control and many food plants come under this category. A description of two plants differing widely in their load characteristics and size will show what can be done in modernizing the operation by the installation of controls. Only the electrical end and part of the refrigerating service will be treated, but this is sufficient to indicate what can be accomplished along these lines.

In the Large Plant

In one plant having two 10 by 10 v.s.a. 2 cyl. compressors driven by 100 hp. motors, refrigeration is used for freezing, hardening and holding ice cream and cooling and holding market milk and cream. An electric power cost saving of 8 per cent was made by changing from manual to automatic operation. A further saving of 4.8 per cent of the power bill was made by the installation of a capacitor unit, to raise the power factor from 76 to 98 per cent. The entire investment will pay for itself in a 39 mo. operating period, a return of about 31 per cent. This plant was about 9 yr. old when these changes were made and was by no means an obsolete plant.

In addition to the two ammonia compressors, the plant contained two large shell and tube type float controlled brine coolers in the basement of the ice cream plant connected by a suitable system of pumps and manifolds to a large, divided, open top brine tank used as a surge and storage. One shell is used for low temperature brine cooling and the other shell for the high temperature brine, the two shells were interconnected so that one could be used for both services if occasion arose.

Operation

A suction line from each shell led to the compressor room, the line from the shell used for high temperature load to the multiple effect ports on the compressors, the other suction line went to the suction header, which, in addition to the shell for low temperature work also took care of the continuous ice cream freezers operated under full flooded conditions and two ice cream hardening rooms held at minus 20 deg. F.

The rooms were of the so called bird cage type and not particularly well adapted for hardening room service. They were operated on a semi-flooded condition by means of a float, was set about 2/3 from the bottom, to prevent slop-over under unusual temperature changes in the rooms.

Brine cooler shells, although equipped with floats were controlled by hand feed, as the float valves were unreliable, and subject to sticking open or closed. The brine in both shells was carried at the same low temperature of from minus 5 to minus 10 deg. F., although the one shell was used for high temperature work such as milk cooling (the milk being cooled to plus 36 deg. F.) and the high temperature storage rooms which were held between plus 36 to 40 deg. F.

The other shell cooled the brine for the batch type ice cream freezers and the freezing tank for popsicles and specialties. Both systems were carried low, so that in case of a freez-up of the shell carrying the ice cream system, the other brine circuit would be at the right temperature to prevent any loss of product in process.

The refrigerating plant was controlled manually. The two suction line system was installed to effect economies in operation, the load, however, was not evenly balanced and the beneficial results anticipated when the original plant was installed did not materialize as the load varied considerably.

It is most difficult and nearly impossible to adapt a constant speed compressor to multiple effect operation on two suction pressures and get economical

operation when the loads on either one or both of the systems vary as greatly and as often as they do in an ice cream and milk plant, so the added investment in compressor and double suction line is seldom if ever, justified under these conditions.

Savings were accomplished in this plant by the following changes. Starters for the compressor and condenser pump motors were wired, to make two units, a compressor and condenser pump forming a unit. Two pressure actuated, mercury tube, double acting switches were installed in the suction line, one for each unit and wired through a small throw-over switch for automatic or manual control. A high pressure cutout, of course was ahead of both control circuits, with the range between 30 in. vacuum and 75 lb. pressure.

The operating range on one unit is set between 0 and 5 lb. and on the second from 2 to 7 lb.

To explain the operation, assume both machines shut down. The suction pressure then raises to 5 lb., the first unit then starts and continues to run until the pressure drops to 0 lb. and the unit shuts down. If however, after the first machine is running, the pressure continues to raise, the second unit cuts in at 7 lb. and both machines operate until the pressure drops to 2 lb. The second unit then stops and the one unit continues to run until another change takes place.

This type of control is well adapted to large systems and in conjunction with brine coolers of large capacity where the lines hold sufficient volumes of gas to prevent a quick pump-out and the large amount of brine in the coolers prevents too rapid a change in the gas pressure.

Brine shell floats were replaced by magnetic liquor line valves controlled electrically by a float valve of the mercury tube type, with a throttling valve on the liquor line to control the rate of flow into the shell. This eliminated the hand expansion control of these shells an unsatisfactory way of operating shell coolers. The replacement in the milk plant, of a milk cooler unit of the internal tube type with a modern compact surface cooler, allowed a much higher brine temperature for cooling milk.

Equipment Changes

This higher brine temperature allowed a pressure of 25 lb. on the brine shell ammonia system. A pressure reducing valve was installed in the suction line from this shell and the brine temperature controlled by the pressure of the ammonia in the shell. The low temperature brine is controlled the same way. The density of the brine is carried to a point 15 to 20 deg. below the lowest temperature corresponding to the pressure of the ammonia in the shell.

To improve the operation of the hardening room, a surge drum of ample proportions was installed on the floor above the rooms and insulated and the liquor level in the drum controlled by a float valve, ahead of which is a magnetic stop valve operating by room temperature through a thermostat in the room most heavily loaded. The room coils now operate under full flooded conditions, the temperature range has decreased, the back pressure has increased and a more uniform condition in the rooms is obtained. A liquor drain line from the bottom of each room header to the ice cream brine cooler shell in the basement below, allows a rapid dumping of liquor from the coils, when defrosting is necessary, decreasing this period from a day or more to an hour or two.

Pressure recorders on the suction line and discharge line of the ammonia system and temperature recorders in the room are indespensable in an installation of this kind and enable the operator to anticipate and correct conditions and help keep the plant running at its most favorable range of pressures and temperatures.

Pressure switch control is not well adapted to small systems or to those not having a brine absorbing medium, as the compressor will pump down the line pressure too rapidly, and after the machine is shut-down, the line pressure will build up rapidly, resulting in frequent starting and stopping.

In the Small Plant

In a small plant, consisting of a low temperature holding room and a high temperature storage room, conditioned by a 6 by 6 in., 2 cyl. v.s.a. high speed compressor, with a standby unit, a control circuit as explained was installed but was later changed to room thermostat control. Under the same conditions the unit had a cycle of 6 times an hour while under the thermostat control, was reduced to one operation every 2½ hr. A pressure switch is still used to guard against low pressure operation.

The control was originally installed to take care of a large cooling load that lasted for 2 hr. a day. The low temperature room now controls the operation of the compressor. A thermostat controls a liquor stop valve ahead of thermo expansion valve, a suction line stop valve, the compressor and the condenser pump. When the large milk cooler load comes on, the milk plant operator (by means of a small throw-over switch) changes from automatic to manual control.

This starts the compressor unit and closes both magnetic valves on the room coil, the liquor and the gas valves, the pressure switch however still protects against low pressure operation. It was found necessary to close these valves on the low temperature room coils because the gas from the milk cooler, operating for only a short period and at a 40 lb. back pressure, entered the same line as the room coil through a pressure reducing valve. The room is held at from 0 to minus 10 deg. F., while the line pressure is around 0 lb. and, although the compressor would be running, a large amount of gas would condense in the low temperature room and slop back to the machine when the system was again put under automatic control after the milk cooling period.

In this plant, the elimination of a small ice freezing tank, two brine cooling tanks, a brine cooled milk cooler, a brine circulating pump, a brine agitating pump and the installation of an ammonia flooded type milk cooler and automatic controls, the elimination of two motors was effected, and the saving in power, during comparable periods of time, was 47.2 per cent. Giving a return on the investment equal to 21 per cent.

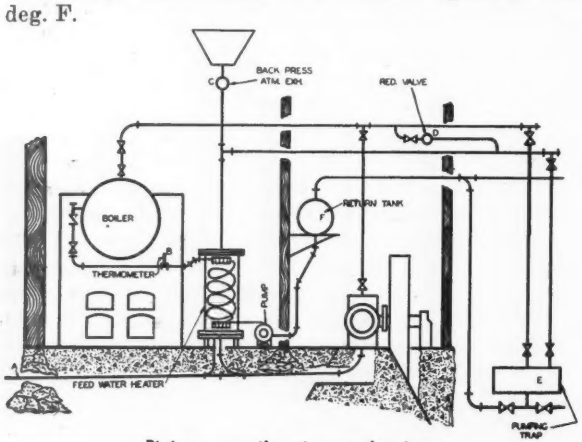
Readers' Conference

Catching the B. T. U.'s

In a small wood working establishment the position of engineer was often vacant. Finally, perhaps three years ago, a young engineer took the job, until he could better himself elsewhere. But this young man was a different type and even though he expected to be there but a short time he started a little figuring bee.

The boiler, a 150 hp. h.r.t. was working 100 per cent as he proved by a barrel and scale test. If he had been burning all coal for fuel he figured that an evaporation of 9 to 1 would mean 5,000 lb. for the 10 hr. run. The coal consumption for the day was approximately 800 lb. burned in addition to the wood waste.

The first bad feature of the plant that he observed was the fact that all returns were thrown away. The next thing was that the reducing valve (D) was in action. The notable thing was that the back pressure atmospheric exhaust (C) was tight. The plant boasted a mercury thermometer (B) which registered 215 deg. F.



Piping connections to pumping trap

After several interviews with the owner and his son, a technical graduate, the engineer finally got permission to install a pumping trap (E) and return tank (F). He expected to get a higher feedwater temperature until the job was nearly completed, then it suddenly dawned on him that such a thing was impossible as the water was heated by a closed heater and could only be approximately as hot as the steam.

The river water he was pumping was just 40 deg. F. and it entered the boiler at 215 deg. F., a rise of 175 deg. F. Then it came to him that the steam used to heat the water meant thousands of B.t.u.'s or approximately $150 \times 30 \times 175 \div 1000 = 787.5$ lb. of steam. Where

150 = b.hp.; 30 = lb. of water per b.hp.; 175 = rise in temp.; 1000 = B.t.u's. per lb. exhaust steam.

The returned condensate was over 200 deg. F. and whereas the drip (A) from exhaust and heater had formerly run a big stream of hot water, it now belched clear steam and had to be trapped. The reducing valve stopped making up low pressure and the 800 lb. of coal stopped although it must be admitted that quite a bit of pipe covering helped in this saving.

Perhaps the finale means more than the rest. That engineer is still there with a seven hundred dollar increase per year in his salary which is no longer classed as wages.

New York City. C. W. Peters.

Fuel Oil Viscosities

What is said in the article entitled Fuels Go High Hat, published in your January issue, about the importance of temperature in the atomization of fuel oil interests me, and because it is so important I would like to call attention to some considerations which might be overlooked.

It is stated that it has been determined by the Navy that the best atomizing viscosity for fuel oil is about 3.2 deg. Engler. I think that such a low viscosity will often be difficult to obtain with the No. 6 oil generally obtainable by commercial users. Of course you can get it if you heat the oil to a sufficient temperature, but this will probably introduce other troubles.

I understand that although the Navy specifies "Bunker C" or No. 6 oil, the oil companies, in order to meet the operating requirements, supply oil of the lowest viscosity in this class, or even oil which might be sold as No. 5.

The ordinary user has little choice as to the rated viscosity, because the A.P.I. Standards allow viscosities ranging from 100 to 300 S.S. Furol, and although it might be possible to heat the oil sufficiently to get 3.2 Engler at the burners, I think that the temperature would be excessive if an attempt were made to get it with 300 or even 150 S.S.F. oil.

Of course the Navy uses mechanical pressure burners almost exclusively. Most burner manufacturers find 180 deg. S.S.U. for mechanical burners, and 300 deg. S.S.U. for steam atomizing burners satisfactory. Now 180 S.S.U. is equal to about 5.4 Engler and if the ordinary commercial user tries to get 3.2 with many of the oils sold as No. 6 I am afraid that he will find himself in difficulties, besides experience has shown that in commercial practice, entirely satisfactory results can be obtained with higher viscosities.

Bloomfield, N. J. James O. G. Gibbons.

The Use of Superheated Steam in Process

In the November issue of Power Plant Engineering is described the use of oil in process work requiring a temperature of 450 to 500 deg. when the available saturated steam temperature was 350 deg. and although the plant has separately fired superheaters the use of superheated steam was not found practical because—"only the peak of temperature curve could be employed, there being no demand for steam at lower temperature—this entailed the total loss of a large part of the heat."

In the first place I do not see why only the peak

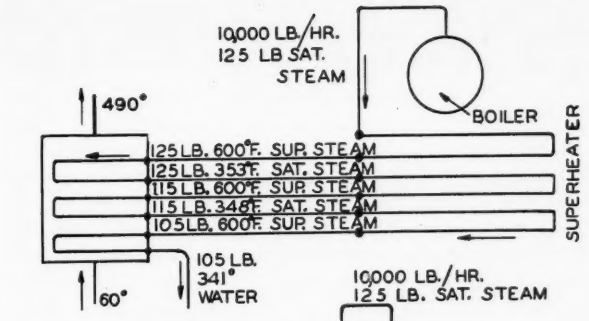


FIG. 1

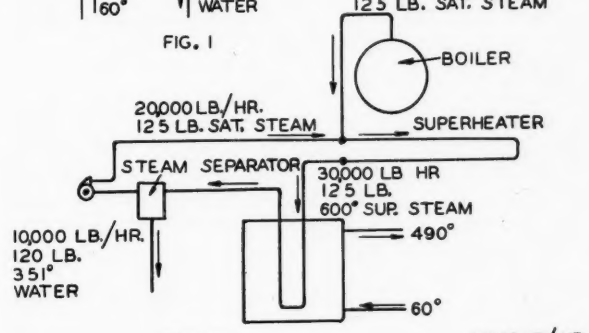


FIG. 2

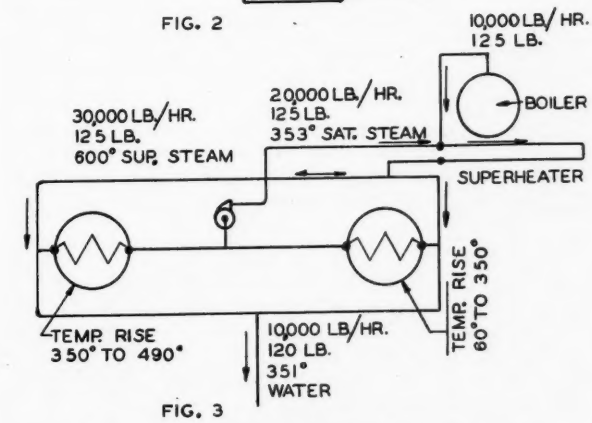


FIG. 3

Fig. 1. Multiple reheat superheater for process cycle
Fig. 2. Process heating cycle employing a circulating pump
Fig. 3. Process heating cycle with storage capacity

of the temperature curve could be used. Regardless of what the final temperature of the process is, the initial temperature of the products that go into the process must be room temperature and this must be raised either in one or more steps from room terperature, which can be taken as 60 deg. to the final temperature which in this case is 450 to 500 deg.

Since this plant is operating at a pressure of 125 lb., saturated steam can be used to heat the products to 350 deg., with steam at much lower pressure for the initial heating if it need be done in more than one step, and the superheat of the steam could be used only for the peak portion.

To be sure, where the temperature of the process is much higher than the saturated steam temperature, there will be saturated steam remaining as by-product, except by special provisions which are explained in what follows, but in many cases there is no necessity resorting to these, because while one process may require high temperature there will probably be other processes that require lower temperature. In such cases, what saturated steam is available as by-product from a high temperature process using superheated steam can be used in the lower temperature processes.

But even in cases where no use can be made of additional saturated steam, the use of superheated steam is not impractical because by re-superheating the steam practically any process temperature can be obtained up to the temperature of the superheated steam without any un-needed saturated steam remaining.

One way of doing this is shown on Fig. 1. By superheating the steam three times a process temperature of 490 deg. can be obtained with 125 lb. steam without any saturated steam remaining if it is not needed. The three superheaters could be either in separate or in the same setting. If the steam is not superheated the maximum process temperature that can be obtained is 350 deg., while the 490 deg. that is made possible with superheated steam corresponds to a saturated steam pressure of over 600 lb.

Figure 2 shows how the same problem can be solved in a different way. In this case there is only one superheater, but a steam pump is used to recirculate two-thirds of the steam going through the process. The same amount of superheating surface will be needed as in the previous case, because although there is only one superheater it must be three times as large. The decision hinges on the relative cost of piping of Fig. 1 as against the cost of the steam circulating pump and cost of circulation of Fig. 2. If the process machinery is close to the boiler room, solution by multiple superheaters will probably be more economical. Conversely, if the distance is appreciable, a steam circulating pump might be a better investment.

The two figures just described illustrate the case of a liquid that enters at 60 deg. and leaves at 490 deg. Where the final temperature is to be maintained for some time, the arrangement shown in Fig. 3 is applicable. All of the superheated steam passes through one container where the temperature is maintained at 490 deg. after being raised from 350 deg., and one-third of the steam then passes through the other container, where it is condensed and can be withdrawn either at the condensation temperature or at a lower one, although the calculations have been made for the condensation temperature on the assumption that the condensate on leaving the process will go direct to the boiler. By the use of valves at the proper places the flow of steam can be reversed so that when the process in one container is completed, the steam will be made to enter the other container first.

I have already mentioned that in many establishments there are some processes that require a lower temperature than others, and in such cases the re-superheating of steam can be dispensed with. For example, referring to Fig. 2, if lower temperature processes require twice as much steam as the high temperature process, then instead of the pump circulating 20,000 lb. of steam for resuperheating, this steam will go to the lower temperature process. In that case the saturated steam will be 30,000 lb., all of which will be superheated and pass through the high temperature process, but on leaving it will have a quality of 33⅓ per cent, which means that two-thirds of it will be available as dry saturated steam.

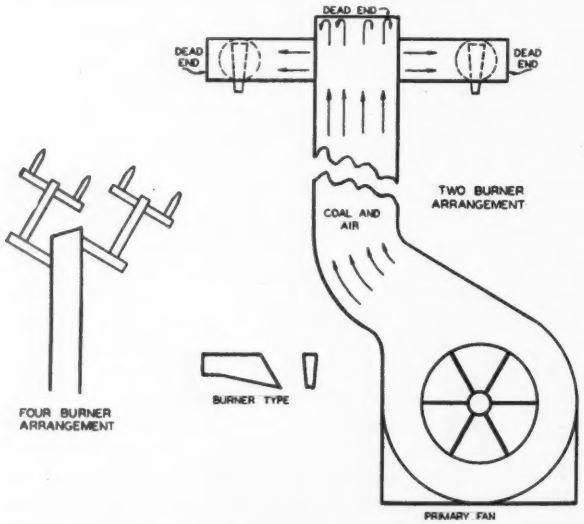
Chicago, Ill. N. T. PEFF.

Powdered Coal Distributor

REFERRING to the January Annual Review number of Power Plant Engineering, article "Fuels Go High Hat", paragraph four, page 25, "From England comes a method of dividing streams of air-borne powdered coal so as to secure even distribution, etc. . . ."

At the Studebaker Corp., South Bend, Ind., in 1931 we developed a method for dividing the fuel discharge from single unit pulverizers into two or more streams to serve as many burners per boiler, two burners were supplied thus on one boiler unit and four burners on another boiler unit.

Prior to this development each boiler was equipped with a large single burner. The original burners were of the horizontal fish tail type. These were superceded by single burners rotary type but neither of these types were satisfactory, both having given poor fuel distribution and having produced too long a flame.



Dead end method of dividing a stream of air-borne coal to secure even distribution to burners

The burners and the arrangement for dividing the fuel-air stream were of simple construction, being made on the job, using sheet metal and arc welding. The most important part of the piping arrangement was the "dead end" principle employed. In substance this principle consisted of having the fan discharge against a dead end in the outlet. This caused the fuel and air to reverse its flow and/or divide evenly into two portions. From there the fuel passed to other dead ends in the piping and on to the burners.

In the case of the four-burner arrangement, the piping was arranged so as first to divide the fuel and air into two streams and then into four streams. The attached rough sketch shows the method employed for both the two-burner and four-burner arrangement.

This method overcame all of the troubles encountered in the previous burners and has been in successful use for 5 or 6 yr.

Apparently one reason for the success of this scheme is that when the fuel and air impinge upon a dead end, the reaction serves to remix thoroughly the fuel and air, then with the same pressure behind each stream and the same furnace draft acting on each burner tip, the division of the fuel is very nearly perfect.

Cincinnati, O. J. E. TOBEY.

Seeing Red to Save Steps

PIPE LINES carrying large volumes of oil or water at high pressures, must be protected against sudden closure of the gate on the delivery end, and, for this purpose, carrying a spring or weight actuated relief valve somewhere in the yard of the main line pumping station.

On one of these 8-in. welded lines, run to its maximum initial pressure of 900 lb. per sq. in. the relief valve would sometimes gradually open as the pressure reached the set maximum, and bleed back into the line a considerable quantity without the gauges at either end to showing that the power was being wasted.

To show when the lever arm of the weighted relief valve began to move, the day engineer fitted up a small flag, a 4 by 6 in. board painted white, mounted so as to appear above the edge of the pit as soon as the line pressure began to raise the weights. By observing this, he was able to regulate station pressures so as to avoid loss of power through uselessly by-passed fluid.

This white flag proved such a help to the day men that a night engineer improved the device by adding a 3-in. reflector of red glass of the type used for rear end protection on bicycles, trucks and wagons. The reflector was set so that it would catch the light from a nearby yard masthead arc light and reflect the red ray directly toward the station office window. By setting a mirror in the office window, and adjusting it so that the pit was visible as the engineer sat at his desk, he was able to note the beginning of by-passing just as effectively as had the day engineer.

Through the combination of flag and reflector, the

This flag and reflector on a relief valve saves power loss and maintenance

former loss of power through useless pumping was completely eliminated, and, where the relief valve and seat had formerly required reseating every 6 mo., they have, since installation of the improved indicating device, now run 2½ yr. without being serviced and are still tight.

Longview, Tex. ELTON STERRETT.

Failure of Armature Banding Wire

THE FAILURE of armature banding wire may result in serious damage to the windings. Failure may be due to overspeed, to rubbing between the rotor and the stator, or to fatigue due to high centrifugal force and the stresses due to mechanical strain and heating. In one case of the failure of a binding band the whirling wire broke the field connection, this resulted in the machine attaining a high speed which caused the armature windings to open out. In a case where a binding hand on an induction motor broke, the loose end of the wire became entangled in the stator winding tearing out the coils and causing short circuits. As a result the insulation caught fire. Overspeed and rubbing between rotor and stator should be guarded against and the bands inspected at intervals so that any pending mechanical failure is seen.

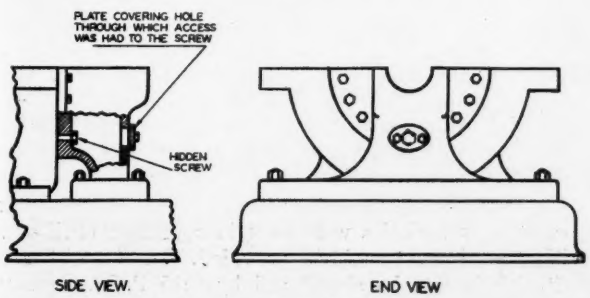
Sussex, England. W. E. WARNER.

Force in Mechanics

THERE ARE many operations in mechanics that can be accomplished only by the use of force, but an engineer should use good judgment in determining whether force is the only recourse, before resorting to it.

Many repair jobs have been caused by resorting to force when coaxing would have been better.

One or two incidents come to mind that illustrate the wisdom of making sure that it is necessary before going too far in its application.



Location of concealed screw

A new expansion joint was to be installed between a steam turbine and its condenser and due to the fact that there was insufficient room to remove the old joint and slip the new one in, the turbine case had to be lifted and moved until the work was completed and then lowered back to position.

The top half of the case and the rotor of the turbine had been removed, the exhaust connection between the turbine and the expansion joint loosened, and the chain falls hitched to the lower half of the case, and tightened enough to take the weight. The screws holding the lower half of the case to the base plate and the bearing pedestals were removed and apparently all that was necessary was to hoist the lower half of the case out of the way.

I have always been loath to challenge the judgment of a machine builder's erector, but in this case, I noticed that the erector's helpers were applying more strain with the falls than should have been necessary to lift the case, and I remonstrated. The erector said that the case was just "stuck" to the bearing pedestal, but finally halted the job until the cause of all the stubbornness should be found.

The bearing pedestal between the turbine and the generator was cast hollow, as indicated in the accompanying sketch, and there was a plate bolted on the side next the generator, for which there was no apparent reason. This looked suspicious and I suggested that the plate be removed.

This was done and, sure enough, there was still one screw holding the bottom half of the case to the bearing pedestal that could not be seen until the plate was removed, the plate covering the hole through which the screw was inserted and through which the socket wrench was operated in tightening the screw.

With the screw removed, the case lifted out as it should but much trouble might have resulted, had not the innocent plate been investigated.

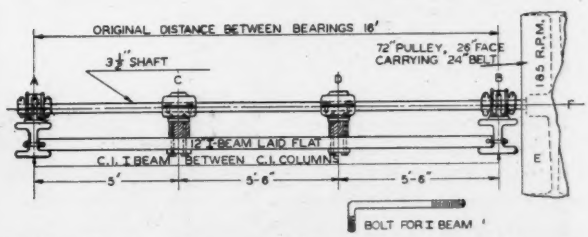
Coffeyville. Kan. EARL PAGETT.

Additional Bearings Stop Whipping in Shaft

THIS FIGURE illustrates what was done to prevent tearing out and replacing a 3½-in. shaft after load of about 125 hp. had been added. Originally the shafting was driven by a 200-hp. motor operated on purchased power. During a series of investigations it developed that that part of the industry using steam generated on the premises as the source of power, was producing power at a lower cost per unit of production than that part of the concern using purchased power. It was decided to rearrange things so as to use steam for power and discontinue the use of purchased power.

After the change and increase in load on this particular shaft, it developed a certain tendency to vibrate or "whip". Time being at a premium additional bearings were tried and proved successful.

A and B were the original bearings, spaced 16 ft. between centers, and E was the pulley belted to main line shaft. There was another bearing as indicated at F not shown. Bearings A and B were set on and bolted to cast-iron I-beams which were in turn bolted to cast-iron columns. A 12-in. I-beam, laid flat was fitted between the cast beams and secured by L-shaped bolts.



After bearings C and D were added the vibration in the shaft ceased

Two bearings, C and D were then mounted. This stopped the "whipping" and bearings A and B cooled down and now run fine. All of the work, except the mounting of C and D which were put on Sunday, was done without shutting down.

Superior, Wis. FRED S. RUTLEDGE.

FLOOD TIDE At Louisville

With all generating facilities out of service, emergency loads are carried from interconnected systems

RECORD FLOODS the length and breadth of the Ohio Valley severely taxed the electric utility systems and in some centers interrupted service for limited periods. Restoration of service immediately following recession of the flood waters in spite of the fact that local generating facilities were out of commission, speaks volumes for the loyalty of utility employees and again demonstrates the value of interconnected systems.

Cincinnati, with both West End and Columbia stations out of service temporarily, was supplied through interconnections for emergency service to radio stations, fire and police stations, hospitals, downtown and limited residential sections of the city. At Columbia the crest of 73.88 ft. was 8.68 ft. above the basement floor.

The Ohio River Station at Evansville, Ind., was kept in service carrying about half load. Water rose to 53.4 ft. within 0.6 ft. of the point where the plant would have had to shut down.

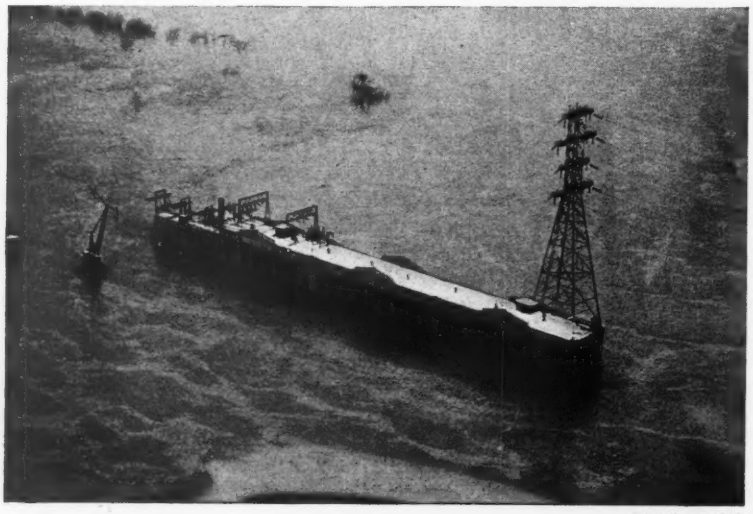
The switch yard was protected from splashing waves and debris by canvas tacked to the fence.

Louisville

Louisville was, of course, hardest hit, the severity of the flood being indicated by the fact that while the normal flood stage of the Ohio River at Louisville is 28 ft., a high water mark of 57.1 ft. was reached at 2:00 A. M. January 27, and this crest remained until 3:00 P. M. of the same day. When the water started receding it went down only half as fast as it had risen. For 13 da. during the flood the water remained above the crest of the record flood of 1884. Although Louisville has been accustomed for years to high waters and floods the previous record was only 46.7 ft. in 1884 with a close second in 1913 of 44.3 ft.

When warnings that the river was rising were given during the week of January 17, the Ohio Falls Hydro Electric station of Louisville Gas & Elec. Co. had already been shut down for about two weeks because of lack of head, a condition usual at this time of year. As soon as the extraordinary rains began to pour water into the Ohio River Valley, preparations were immediately made to protect all of the company's plants. On January 18, several days before official warning of the disaster, the company called on the Public Utility Eng. & Serv. Corp., advising officials of that corporation of the seriousness of the situation. As the waters continued to rise, constant efforts were made to protect the turbine tops from water by building bulkheads.

The steam generating plant at Waterside Station, Third and River streets, was constructed to withstand water approximately 2 ft. higher than any flood in the history of the city. The Canal Street Station, an auxiliary generating plant, is located on a still higher point than the Waterside Station. By the morning of January 24, it became apparent that neither of these stations could be kept operating, but service was kept on as long as possible as an aid in evaluating the flooded area. Telephone communication and other emergency agencies were kept in operation until auxiliary equipment could be provided. The Canal Street Station had to be abandoned by 8:15 P. M. Sunday, January 24, and the Waterside Station at 11:40 P. M.



(Acme Photo)

Fig. 1. The Ohio Falls hydro plant, normally out of service at this time of year due to lack of head, just manages to keep above water

the same evening, the latter station having been kept in operation by letting the water that was leaking into the station run into the condenser wells one at a time and using them as sumps, the pumps being able to keep the water off the turbine floor until about 10 o'clock in the evening. The line of the Dix river dam between Louisville and Shelbyville had been wrecked by floating debris on Sunday afternoon.

At 2:50 A. M. Monday morning, January 25, a rural line of the Louisville Gas & Electric Co. was tied to one of the Kentucky Utilities Co. near Middletown, Ky., after an emergency connection had been made southeast of Shelbyville. A small amount of current was fed to Radio Station WHAS, engaged in flood relief communication only, some few dairies and relief stations. A 10,000 kw. transformer of the Kentucky Utilities Co. was moved by rail from Shelbyville to a point on the Dix River dam high line near Lyndon, Ky., and at 4 P. M. of Thursday, January 28, current was turned into the Highland substation and through that into the Highlands, a Louisville residential section. The next day the current was extended into the Crescent Hill section. These sections served as refugee areas and operating points for all relief work. Shortly afterward the service was extended to Middletown, Anchorage and Pewee Valley, suburban communities which had been turned into refugee camps.

Power from a pool formed east and north of Louisville was brought to the busses at the Waterside Station through Cincinnati and Indianapolis at noon, Wednesday, February 3. All of the underground and part of the overhead systems were still under water. Lines were cleared, transformers tested and other apparatus rehabilitated as quickly as possible and surveys made to determine what customers were able to use the current.

Although no electric generating plants of the Louisville Gas & Elec. Co. was in operation in Louisville by the third week in February, a peak load of over 40,000 kilowatts was being carried through interconnection with Cincinnati and with Indiana and Kentucky utility companies. The company's normal load in Louisville at this time of the year is about 70,000 kilowatts. At the last report it was expected that a 25,000 kw. unit at the Waterside Station would soon be put in service, followed soon by another 20,000 kw. unit. All substations were then in service except two, both of which are used exclusively for railway service.

Fig. 2. Normally the generator room of the Ohio Falls station is like this. The picture was taken several weeks before the flood

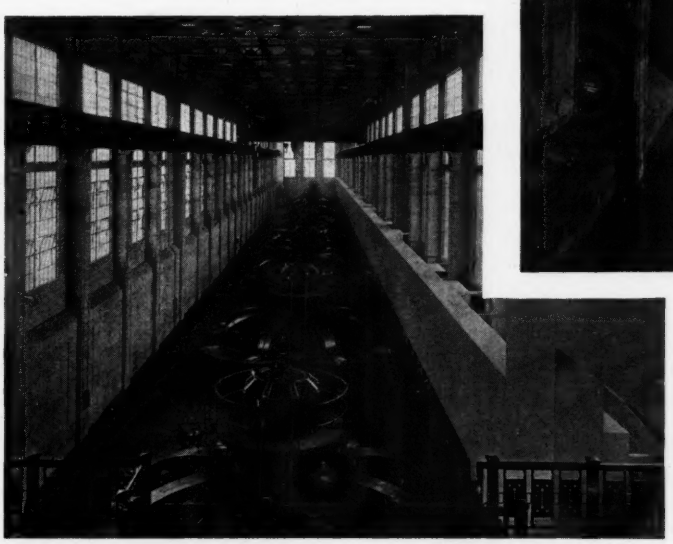


Fig. 3. The receding flood waters leave a mess of wreckage and debris. When this picture was taken, the exciters were above water, but high water levels extended up to the light line visible on the walls

By February 17 the underground network in the business section was in condition to provide 100 per cent service, but all customers are not ready to make use of the service because in many of the districts that were inundated, wiring, conduits, etc., had to be dried out, inspected and approved by the city inspectors before energy could be placed on the lines. Radial underground cable, 4000 v., was then ready to render about 70 per cent service and was expected to be able to give complete service by February 20. The overhead distribution system, except in those districts where greatetst property damage resulted from the flood, was ready to handle practically all customers whose equipment and wiring facilities were ready for use.

Electrical Engineers Look at Tensors——

SOME of them, at least, sailed for Bermuda—the lucky ones. The others, and they were greatly in the majority, took another look at tensors and around New York and then went back home to work after a splendid week of technical meetings and enjoyable social activities.

Things are picking up. For the first time in several years the American Institute of Electrical Engineers put on a five-day winter convention instead of the usual four-day meeting and then topped it off with a post-convention cruise to Bermuda. Needless to say, even with the additional day the time was only too short, for, as in previous years, the technical program involved the presentation of a large number of technical papers and even with the time for presentation and discussions reduced to the barest minimum, there was still never time enough for full discussion.

It was, however, a splendid meeting and whether one was interested in the strange symbolisms of tensor algebra, or dyadics or the ultra rapid reclosing breakers of Philip Sporn, or only in the verbal niceties of Louis Egan at the Edison Medal meeting, there was something of interest for everybody. As a matter of fact not the least important was the presentation of the Edison medal to Dr. Alex Dow. After all, one can hear good technical discussions most any day, but one is not often privileged to listen to such a fine and understanding address as was given by Mr. Dow upon receiving the Edison medal. For Dr. Dow is preeminently the dean of public utility men in this country, and though he disclaimed being an eletrical engineer, his long fine record in the utility field makes him as deserving of the high honor of the Edison medal as any of its distinguished previous recipients. Despite his years Mr. Dow has lost none of the fine mental qualities that have made him such a great leader in the utility industry.

Aside from the technical sessions there were many features of general and social interest: There was the smoker on Tuesday night, held this year in the Grand Ball-room of the Hotel Commodore, the annual dinner-dance at the Astor on Friday, the Edison medal presentation already referred to, many interesting inspection trips and for those fortunate to have the time and means, the post-convention cruise to Bermuda. Some twenty-five groups participated in this event. The total attendance at the convention was 1143.

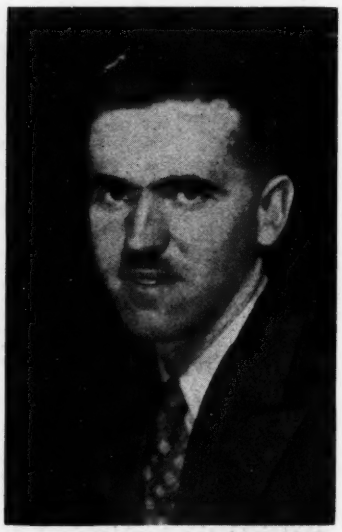
It would be unwise to attempt to present a detailed report of the 56 papers presented at the 13 technical sessions of this convention, first because it would entail more space than is available here and secondly because many of the papers were of a highly specialized nature of little interest to those concerned primarily with the generation, transmission and use of power. We shall, however, consider those papers which are either of outstanding general importance or which are of specific interest to those in the power industry.

What Are Tensors?

Outstanding among the technical sessions were the two on Tuesday devoted to the subject of Tensor Analysis.

These sessions were attended not only by electrical engineers but by a number of eminent mathematicians who had been invited to participate in the discussion. Their point of view was extremely interesting and their sane discussion of the situation did much to bring the proponents of tensors and the skeptics to a better understanding.

For, as in the case of any new development, there are skeptics—those who will not admit at the present stage of development that tensors are all their protagonists claim for them. On the other hand, are men like Kron and Boyajian, who feel that tensor analysis is a tool of utmost value and importance in electrical engineering and that its further application will permit the solution of complex electrical engineering problems not easily subject to other methods of mathematical attack.



ABE TILLES
who was awarded the Alfred Nobel Prize in Electrical Engineering for the year 1936. The award was made for his paper "Spark Lag of the Sphere Gap" presented at the Pacific Coast Convention in Aug. 1935. The Alfred Noble prize was instituted in honor of Alfred Noble, past president of the Am. Soc. of Civil Engineers

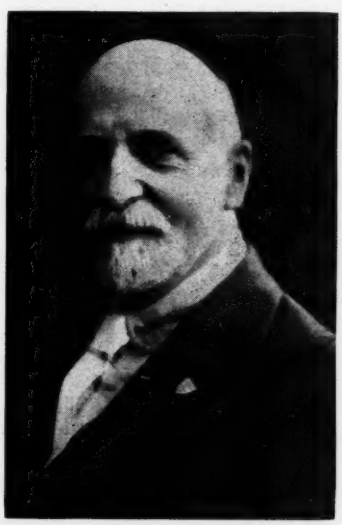
Tensor analysis has been in use for some time in dealing with relativity problems, but it is only recently that they have been applied in the field of electrical

Then Sail For Bermuda

engineering. Chief among its proponents in this field is Gabriel Kron of the General Electric Co. His enthusiasm for the subject is admirable and his keen insight into and his remarkable ability in applying this branch of mathematics to the electrical engineering field has done more to stimulate interest in the subject than all other factors combined. In the short two years that Mr. Kron has been expounding the theory of tensor algebra and demonstrating its use, in a series of articles in the General Electric Review, interest in the subject has grown to such an extent that those in charge of the technical program of the winter convention thought it of sufficient importance to devote an entire day to it. We are, however, a little ahead of the schedule.

The technical program really opened on Monday afternoon with two simultaneous sessions, one dealing with communications and the other devoted to a group of four papers on selected subjects. The communication session was highly specialized, of little interest to anybody except specialists in the field, but the other session had at least two papers of general interest. The first of these was a paper by H. J. Reich on Electronic Transient Visualizers. This paper pointed out that while cathode ray oscillagraphs have become extremely useful tools in the hands of operating engineers, research technicians, etc., their usefulness has been limited almost entirely to the observation of sustained periodic phenomena, and that it has been of little use in the study of transients. To extend its usefulness the author had developed the apparatus described in the paper, which involves a method of repeating the transient in synchronism with the sweep voltage. A transient visualizer accomplishing this result by means of a relay opened and closed by the sweep oscillator had previously been developed by the author and while this functioned well at low frequency, it had the limitations imposed by relay inertia and contact chatter. These limitations were now removed by replacing the relay with a vacuum tube circuit. By means of a comparatively simple vacuum tube switching circuit the transient, whatever it may be, is repeated periodically so that it may be visualized on the screen of the oscilloscope.

A. M. MacCUTCHEON
President of the American Institute of Electrical Engineers.



ALEX DOW
who was awarded the Edison Medal.
He disclaimed being an electrical engineer but admitted that he had done certain things in the utility field and if these things merited the award, he was pleased and grateful to accept it.

The other paper at the Selected Subject session of general interest was one describing a New Electrostatic Precipitator by G. W. Penney of the Westinghouse Co. The cleaning action upon gases of a corona discharge have been known since 1824 and electrostatic precipitators have been in commercial use for many years in chemical industries and in power plants. The new precipitator described by Mr. Penney is not fundamentally different from older types, but involves a more accurate application of the principles of electrostatic precipitation and in its design and construction is a much more compact and unified apparatus than older units.

Tensors

The day devoted to the subject of tensors proved to be a most interesting day. Mr. Kron and Mr. Boyajian were the principal spokesmen for tensors.

Prof. A. Pen-Tung Sah, of the National Tsing Hua University, was concerned not directly with tensors but with a related branch of mathematical analysis. His brilliant presentation of two papers excited the admiration of all in attendance. L. V. Bewley was one of the skeptics so to speak, and his paper on the use of tensor algebra in transformer circuits was an effort not so much to demonstrate the value of tensors as it was to prove the superiority of other more conventional methods.

Altogether, five papers were presented at these sessions. Mr. Boyajian opened the session with a paper entitled, "The Tensor—A New Engineering Tool." This paper, as its title indicates, was of an introductory nature, designed primarily to explain what tensors are, together with a brief discussion of their application. Like Mr. Kron, Boyajian is very enthusiastic about this development and he predicted that in time tensors will become the universal language of electrical engineering.

In this paper, Mr. Boyajian referred briefly to the history of tensors. Tensor algebra, he said, was developed by Ricci and Levi-Civita as a tool in advanced geometrical analysis, but it has since found extensive applications to relativity and related field problems. Its value as a tool in electrical engineering has been amply and beautifully illustrated by Gabriel Kron in a long series of articles still appearing in the General Electric Review. In this series of articles Kron demonstrates the use of tensors by applications to rotating electrical machines and complicated static circuits.

Perhaps the major reason for the power and value of tensor analysis, at least from the standpoint of the electrical engineer, is its ability to generalize from simple individual cases to complicated groups and systems and to deal with them wholesale. By a remarkably comprehensive and yet simple notation and symbolism, tensor analysis makes manipulation of complicated systems very convenient. Information that would ordinarily require many long rows of simultaneous equations can be packed into a single short, self-explanatory tensor equation. But, as Mr. Boyajian pointed out, tensor analysis is far more than a mathematical shorthand. The comprehensiveness of its notation is just a consequence of the comprehensiveness of its conceptions. By a method of analysis which is particularly adapted to generalization, tensor analysis automatically leads to the most generalized formulation of a problem. If an equation of the problem can be written for the simplest case with only one degree of freedom, in tensor form it becomes the formula for any number of degrees of freedom of the problem. For instance, Ohm's law for a single circuit expressed in tensor form becomes Ohm's law for all networks, whether conductively connected or inductively coupled; the equation of a single coil moving in a magnetic field expressed in tensor form becomes the general equation for all rotating machines; the equation of the stationary line becomes the equation for all transmission systems, etc. The full significance of this is brought home to the electrical engineer more clearly when he begins to see that, heretofore, every time he had a little different machine or a little different system, he had to start from the ground up to develop equations for each case, whereas tensor analysis enables him to write general equations applicable to all possible variations and elaborations of his machine or system. Furthermore, by a system of formulation which is independent of the type of units, co-ordinates, "measure codes," or system elements used, tensor analysis expresses generalized relationships in a universal language independent of specific views. The electrical engineer comes to recognize the significance of this when he discovers that his equations have generally been based on specific co-ordinate axes (circuit terminals), and that every time his point of view changed, his equations have had to change; while his equations in tensor form remain unchanged no matter what new point of view and lines of approach (terminals) are followed to his system.

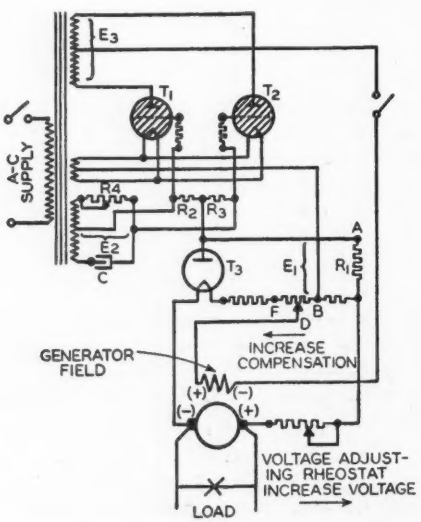


Fig. 1. Schematic diagram of electronic voltage regulator.

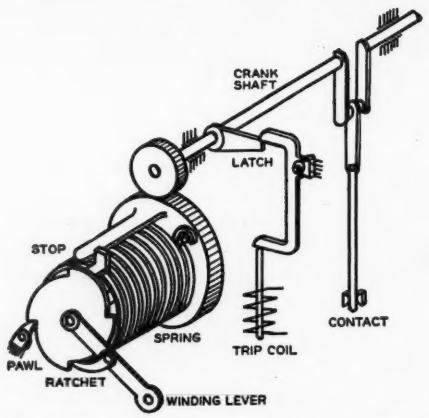


Fig. 2. Fundamental principle of the mechanism involved in the service restorer.

Finally, by certain generalized and standardized operations, tensor analysis makes the transformation of the specifications of a problem from one set of coordinate axes to another a routine matter.

So much for Boyajian's paper. We have abstracted rather fully from it because it presents a picture of Tensors, at least as seen by one of its proponents.

In the paper by Bewley, he showed the application

of tensor algebra in Transformer Circuits. He, however, is not convinced that tensors are all that Kron and Boyajian claim for them and in showing the application of tensor algebra to transformer circuits, he also solved the same problems by means of two other methods of mathematical analysis. In presenting these three methods side by side it was his contention that the tensor method was no shorter—in fact longer than the more accepted methods and that it had no particular advantages. As a matter of fact, in closing his paper he said that, given the necessary time, he would guarantee to rewrite any paper appearing in Electrical Engineering and using the methods of tensor analysis, in less space by using one of the more conventional methods of attack.

That statement naturally brought forth fire from Mr. Kron. "People," he exclaimed, "do not see the difference between 'notation' and 'methods of reasoning.'" Tensor analysis, he said, is a method of reasoning. It is of no import whether one can solve a particular problem by some other method which may be shorter, the thing of great importance is that with tensors the simplest specific case at once becomes the broad general basis for dealing with all similar problems regardless of how they differ superficially. Whereupon Mr. Kron proceeded to demonstrate the beauty and simplicity of the tensor method upon the blackboard.

The discussion of the mathematicians was of distinct interest, since they have been familiar with tensor algebra for some time. Dr. Hoffman of Princeton University said that the tensor method was much simpler than ordinary differential calculus, but of course that, he said, was rather a strange statement to make, since must know differential calculus to use tensors.

Dr. Oswald Veblin, of Princeton, also discussed the subject briefly. He pointed out that there was no reason for any controversy—that perhaps there were faults in the papers presented, but this was no reason for condemning it. In the end all its present shortcomings, if any, would be ironed out and the method would take its proper place in the art.

Dr. Jos. Slepian was somewhat on the side of the critics, but as he explained, after listening to the discussion in the morning and after sitting next to Prof. Veblin at lunch, he felt like rewriting his prepared discussion and he took care to soften the severity of his criticism. His example of the New York Stock Market report as a possible form of tensor was amusing.

Mr. Bewley in summing up the discussion was still unconvinced. He said that the use of tensors in many instances was like dragging up a cannon to shoot a sparrow.

Restoring Service in the "Wink of an Eye"

There were two other sessions on Tuesday besides the two sessions on Tensors. One of these was on Power Transmission and the other on Power Distribution. The power was concerned largely with papers on lightning investigations or transmission lines and methods of lightning protection, but also included a paper on the electrical characteristics of suspension insulator discs and a report of power system stability. The Power Distribution session was more diversified, including as it did, papers on secondary distribution, pole flexibility, over current protection and automatic boosters.

Both the Induction Machinery and Synchronous Machinery sessions on Wednesday were rather specialized, the papers dealing largely with design problems of rather fundamental nature. The two other sessions one on Protective Devices and the other on Electonics, were of more general interest. The paper, Ultra-High Speed Reclosing of High-Tension Transmission Lines, presented by Philip Sporn and D. C. Prince, at the protective devices session, was of considerable general interest since it described equipment for reclosing high voltage circuits at the highest speed permitted by certain physical phenomena, particularly arc deionization. This paper described the reclosure of circuit breakers following a fault with a minimum of delay in order that synchronous load will not fall out of step.

A new automatic service restorer for use on low capacity circuits was another feature of the Protective Devices session. This equipment involves a mechanism having a manually wound spring which when fully wound stores enough energy to give 3 closing and 4 openings. The arrangement is shown in Fig. 2. One end of the spring is connected to a rewinding lever and the other, through a 4-to-1 reduction gear, to a crankshaft to which the blades are connected.

The crankshaft is fitted with a latch plate engaging a latch to hold the breaker closed with the spring wound. The latch, which is actuated by a series trip coil in each pole, is released on overload, permitting the contacts to open at high speed under the action of the spring. There being no latch to hold it open, the switch recloses and remains closed until the latch is again released by one of the trip coils, except in the case of the last opening, when it locks in the open position.

Mr. Sporn's paper was received with particular interest. As E. E. George pointed out in the discussion, Messrs. Sporn and Prince have put into practice that which some of us have talked about for years. This paper, as a matter of fact, regards circuit breakers in a new light and as Mr. McNeal of Westinghouse said, the definition of a circuit breaker needs remodeling. Instead of being regarded as a device to open a circuit, it should be thought of as a device to keep service on the line.

"It used to be," said Mr. Sporn, in his discussion "that when a fault occurred and the breaker opened, it remained open for 2 minutes. Later on we began to think about the question more carefully and now we open the breaker in the shortest possible time and then reclose it in an equally short time."

Electronics

At the Electronics session Wednesday afternoon the most interesting paper to power men was the one by F. H. Gulliksen of the Westinghouse Co. on an Electronic Voltage Regulator for D. C. Generators. This paper described a voltage regulator using grid-controlled arc-discharge tubes as rectifiers under the control of a diode to supply field current for d.c. generators. As the author pointed out, electronic voltage regulators for d.c. generators have been available com-

mercially during the past 4 years, but these regulators, which have a sensitivity of ± 0.1 per cent, are too expensive for many industrial applications, for which the less expensive electromagnetic type of regulator gives satisfactory operation. The regulator described in this paper and shown schematically in Fig. 1, forms the next logical step in electronic regulator design, namely, a regulator that can compete with some of the conventional electromagnetic regulators on a price basis, is more sensitive, and has faster response characteristics. This new regulator has demonstrated an over-all sensitivity of plus or minus 0.5 per cent with a supply voltage change of 10 per cent, but it requires an a.c. supply. It is therefore useful in d.c. regulator applications where an auxiliary source of alternating voltage is available, which includes all installations of a.c. motor driven d.c. generators. Fundamentally the regulator is a grid controlled full wave rectifier supplying rectified current to the generator field. The grid control is obtained through the action of the diode T_3 whose anode current is a function of the generator armature voltage.

Electrical Machinery

The electrical machinery session on Thursday morning was of unusual general interest. Four papers were presented at this session, as follows:

1. Self-regulated Compounded Rectifiers. By W. M. Goodhue and R. B. Power of Harvard University.
2. Abrasion—A Factor in Electrical Brush Wear. By V. P. Hessler, Iowa State College.
3. Arc Characteristics Applying to Flashing on Commutators. By R. E. Hellmund, Westinghouse Electric & Mfg. Co.
4. Contact Drop and Wear of Sliding Contacts. By R. M. Baker and G. W. Hewitt, Westinghouse Electric & Mfg. Co.

The paper on the Self-Regulated Compounded Rectifier was perhaps the most interesting delivered at this session since it described a new circuit which permits a mercury vapor rectifier to function as its own automatic regulator with the aid of a novel grid control arrangement. The control equipment is practically inertialess and therefore almost instantaneous in its operation. Furthermore, the circuit may be compounded with respect to load current and input voltage giving a wide variety of characteristics ranging from cumulative compound to constant current. These characteristics cover a wider range than do those easily obtained from d.c. generators. This development was fully described in a recent issue[1] and need not be referred to in detail here, but it was received with a great deal of interest and provoked animated discussion. For, as the authors of the paper pointed out, this development opens up a new field of power rectifier technique and application. The principles of self-regulation and compounding may be applied to almost any variable. Self-regulation becomes automatic control and thus enters into an infinity of control applications; the conversion of constant-potential input into constant current d.c. output, without the use of capacitors or a.c. reactors may be applied either for power transmission or power utilization. It was but natural that a development with such implications should be regarded with great interest and this paper also was given considerable discussion.

While the merits of this system was generally appreciated, some of the members seemed to think that it might be expensive for a small installation. The authors explained, however, that the multiplicity of apparatus was deceiving for many of the devices used —the current transformers, for example, were very small, smaller even than ordinary filament transformers and that the expense was not a limiting factor.

Mr. Rockwell of A. T. and T. presented a simpler scheme, less expensive, but the authors explained that this system (the one presented by Mr. Rockwell) was what had started them off on this investigation.

Professor Dawes commented very favorably on the development. He stressed the growing importance of the mercury arc rectifier in industrial service and that this development of Goodhue and Power had attractive possibilities.

The remaining three papers presented at this session were all devoted to different phases of brush operation and commutation and were therefore related.

V. P. Hessler in his paper on Abrasion reported the results of tests on the rate of brush wear of anode and cathode brushes, and of brushes carrying current and those that did not. These showed that abrasion is an important factor in eletrical brush wear. His principal findings were as follows:

1. The wear of brushes on concentric rings is largely abrasion resulting from a ring condition established by the current flow.
2. The abrasive ring condition is caused by the cathode brush for carbon or graphite brush materials, but is caused by the anode in the case of metallic brush materials.
3. The abrasive action of the anode metallic brush path is much more pronounced than of the cathode carbon or graphite brush path.

R. M. Baker and G. W. Hewitt in their paper reported the results of a series of experiments in which the processes of contact voltage drop and ring wear in sliding contacts were demonstrated by a direct method. The results of these tests showed that the wear of metal-graphite brushes and the rings upon which they operate can be reduced if they be operated in an oxygen-free gas instead of air.

As Professor Hessler pointed out, the question of brush wear and moving contact phenomena is exceedingly complicated and while much has been learned in the past few years, many questions still remain unanswered. The oxide film, which is so important, is not the whole explanation of movable contact drop. As he put it, there are three things we must know before we can expect to solve the practical difficulties of brush operation. First, we must know the explanation of contact drop; secondly, we must understand the mechanism of wear; and, third, we must know more about friction.

The remaining sessions on Thursday were devoted to papers on electrophytics, instruments and measurement and on electric welding.

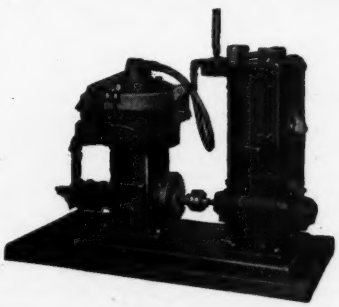
The convention closed on Friday with a number of interesting inspection trips to various plants around New York.

[1] Page 108, February 1937 issue.

New Equipment

Oil Purifiers

REMARKABLE PERFORMANCES of Diesel engines in many new fields has resulted in a great increase in the number of small and medium sized Diesel engines. The trend in design has been to higher rotative speeds with higher piston and valve speeds and they must be properly lubricated with clean oil continuously. Oil refineries are meeting this situation by producing high quality Diesel engine lubricating oils. The function of the Hydroil



Purifiers is to maintain the original lubricating value of the oil.

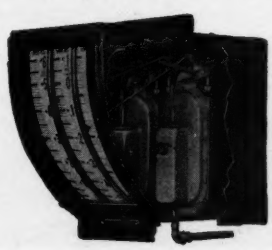
Higher rotative speeds require correspondingly faster moving parts in the fuel system. Multiple cylinder construction and modern design of injection nozzles require very small openings. For satisfactory performance, Diesel fuel must be clean and free from water. The 400 Series Goulds Hydroils have been developed to enable the modern small or medium sized power plant to obtain efficient purification at low cost. They are simple in design, easily operated, substantially constructed, compactly built, and will perform their duty at low cost for many years.

They are supplied in three sizes for application with Diesels of up to 1200 b.hp. and have a range of from 30 to 100 gal. per hr. of lubricating oil and from 50 to 125 gal. per hr. of fuel oil.

Multipointer Gage

A NEW DIAPHRAGM OPERATED multipointer gage has been developed by the Bailey Meter Company, Cleveland, O., for boiler room service. Of paramount importance in this new development is its diaphragm material, which is resistant to oil, acid, caustic and heat. It possesses exceptional flexibility with strength said to be in excess of animal skins and tissues of the goldbeater type.

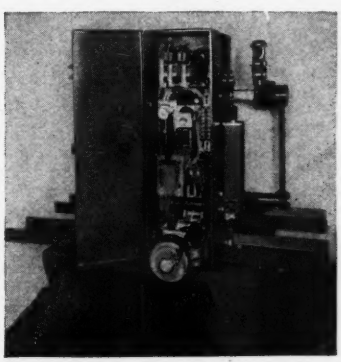
Draft is applied on one side of the diaphragm as shown, which causes a corresponding movement of the system. This movement is opposed by a flat calibrated spring. The motion is transmitted by the sealed link to the outside of the diaphragm unit where a drive link carries the motion to the indicating pointer. For indication of pressure the connection is made on the opposite side of the diaphragm, and for indication of differential pressure the connections are made to both sides of the diaphragm.

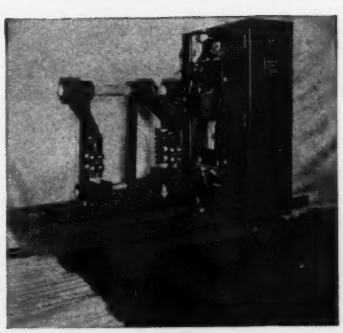


The diaphragm units are available in casings containing from one to twelve units, may be surface, semi-flush, or full flush mounted.

New Mechanism for Oil Circuit Breakers

A NEW AND IMPROVED operating mechanism for the Type FH line of oil circuit breakers has been announced by the General Electric Company. Designated the MK-110, the new mechanism supersedes the Type MK-10. By increasing the opening springs and modifying the trip-mechanism to reduce the friction, faster open-





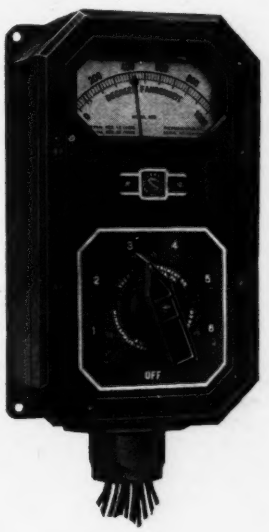
ing time is obtained. This permits rating all breakers—600 amp. to 4000 amp., inclusive—at eight cycles.

Other improvements in the mechanism include an easily operated hydraulic device for manual closing. It is portable and can be operated by one hand. The centrifugal mechanism has been modified to give greater rigidity and ease in alignment at all motor speeds. An improved cut-off switch, more easily adjustable, has been provided. Both the motor and the cut-off switch in the MK-110 mechanism are interchangeable with the motor and cut-off switch of the Type MK-104 unit, used with outdoor and other indoor breakers.

Diesel Pyrometer

DESIGNED ESPECIALLY for Diesel engine service, a new pyrometer has just been announced by the Brown Instrument Co., Philadelphia, Pa. It is available in three temperature ranges—namely, 0-1000 deg. F., 0-1200 deg. F. and 0-1600 deg. F. and with the following combinations of switch points: 4, 6, 8, 12, 16 or 24. The 0-1000 deg. F. range instrument is also available with "cold," "normal" and "danger" operating zones plainly indicated on the scale.

The pyrometer case is of light weight molded bakelite to assure a permanent finish and is thoroughly water proof. A dial



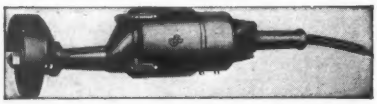
type switch, integral with the pyrometer is mounted in a separate compartment of the pyrometer case, enabling an operator to select temperature indications with the utmost convenience from any number of thermocouples in combinations mentioned above. The pipe fitting is suitable for back or bottom connections.

An enameled metal scale is 3 7/8 in. wide, and is printed in black and white. Each pyrometer is calibrated within 1 per cent of full range in the normal operating zone and within 2 per cent outside that zone. The new Brown Diesel engine pyrometer is available for use with Brown IC Thermocouples.

AIR CONDITIONING, a correspondence extension course offered by Rutgers University, New Brunswick, N. J., has been revised to keep it abreast of newer applications, by rearrangement, insertion of new sections and addition of tables, and illustrations of typical devices. Usually in utility companies a group is formed to meet for discussion in addition to the home study, although the correction and grading of papers is done directly by the university. The course covers Heat Phenomena and Transfer, Humidity, Heating, Cooling and Humidity Control, Refrigeration, Air Distribution, Control Apparatus for Air Conditioning Systems, Applications, in fourteen sections.

Portable Grinding Tool

THE CHICAGO PNEUMATIC TOOL CO., 6 East 44th St., New York, has recently placed on the market a new portable electric grinder, incorporating a totally enclosed, fan-cooled motor. It is intended for general purpose grinding, and with



additional wheel equipment, for wire brushing, buffing and polishing of all types of metal surfaces in all types of plants. The motor is completely encased in copper shield which excludes dust and conducts motor heat to cooling air. A fan forces a strong current of air over this shield and out over the gear case onto the work.

New Insulating Brick

A NEW TYPE of 2000-deg. insulating brick known as "JM-20" is announced by Johns-Manville. This new brick was developed by the company's research laboratories for use behind refractory walls in various types of high temperature industrial equipment, including boiler settings, ceramic kilns, steel plant equipment, and practically all types of furnaces. It can also be used for direct exposure at temperatures up to 2000-deg. F. wherever there is no flame impingement, slag action or mechanical abrasion. This insulating refractory is produced by combining a high quality refractory clay with a specially manufactured fibrous, light weight, inorganic aggregate.

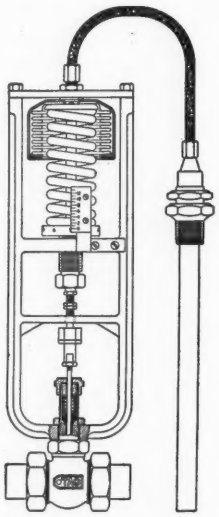
It is unusually light in weight, weighing less than 1.7 lb. per standard 9-in. equivalent. Its heat capacity is unusually low as is also its thermal conductivity.

Power Equipment for Oil Tankers

EQUIPMENT of the four new bulk oil tankers recently ordered by Standard Oil Co. of New Jersey will include for each ship two Foster-Wheeler boilers to generate steam at 400 lb. gage and 750 deg. F. with economizers, a Foster-Wheeler condenser for 28¼ in. vacuum; double reduction De Laval steam turbines, cross-compound, the high-pressure at 6000 r.p.m., low-pressure at 5000 r.p.m. to deliver 3000 hp. at the propeller shaft; feedwater to be heated in three tubular heaters bleeding steam at 100, 35 and 6 lb. abs., also using exhaust from the feed-pump turbines which drive 2-stage centrifugal pumps at 6000 r.p.m., delivering 65 g.p.m. from 70 lb. suction pressure against 1160 ft. head. At sea, current will be supplied for motors and lights from a generator coupled to the low-pressure intermediate gear shaft, while for port use and standby two 300-kw. generators are driven at 1200 r.p.m. by geared De Laval steam turbines running 10,000 r.p.m. on 375 lb. and 725 deg., exhausting to vacuum. Oil purification is by De Laval purifiers with lead bowls of 150 gal. per hr. capacity. At full load a shaft horsepower is expected for 0.58 lb. of class C bunker oil per hr. for all purposes.

Controllers

C. J. TAGLIABUE MFG. CO., Park & Nostrand Ave., Brooklyn, N. Y., announce improvements in its line of self-operating temperature controllers. These improvements include an entirely new design of flexible seamless metal bellows and numerous minor refinements of design, material and workmanship.



This new model is suitable for industrial applications where the close control obtainable with auxiliary power is not necessary or where the steam pressure available is less than 10 lb. per sq. in. Temperature ranges are approximately 75 deg. between the limits of 30 deg. F. and 450 deg. F. The valves are semi-balanced, in sizes from ½ to 2 in.

DIRECTORY for 1937 of Association of Consulting Chemists and Chemical Engineers, at 50 E. 41st St., New York, N. Y., is now available, giving names, addresses and specialties of the members.

John C. Page, New Commissioner

OFFICIALS of the Bureau of Reclamation conferred in Washington on current problems connected with the largest construction program so far undertaken in the field of water conservation. Meeting during the last week of January, they outlined the work of the Bureau for the coming year. Left to right, seated: H. W. Bashore, in charge of the Casper-Alcova project with headquarters at Casper, Wyo.; Raymond F. Walter, Chief Engineer, in charge of the engineering staff at the Bureau's Denver, Colo., office; John C. Page, Commissioner, Bureau of Reclamation, Washington, D. C.; Jack N. Savage, in charge of the Dams and Designing Section at the Denver engineering office; Standing, left to right, Walker R. Young, in charge of the Central Valley project in California with headquarters at Sacramento, Cal.; Frank A. Banks, in charge of the Grand Coulee Dam and Columbia Basin project with headquarters at Coulee Dam, Wash.; R. B. Williams, in charge of the All-American Canal and Gila Valley projects in Arizona and California with headquarters at Yuma, Ariz.; and Ralph Lowry, in charge of the Boulder Dam with headquarters at Boulder City, Nev.

John C. Page, Commissioner of the Bureau of Reclamation, was born in Syracuse, Nebraska, October 12, 1887, educated at the University of Nebraska and Cornell University, and entered the Reclamation Service soon after. The late Dr. Elwood Mead called Mr. Page to Washington October 1, 1935, to assist in the Commissioner's office as head of the engineering division. Shortly after the death of Dr. Mead last January Secretary of the Interior Harold L. Ickes appointed Mr. Page as temporary head of the Bureau of Reclamation with the title of Acting Commissioner. He was appointed Commissioner by the President January 25.

The Bureau of Reclamation, operates in 17 Western States in that arid and semi-arid region lying west of the 100 meridian and comprising about one-third of the territory of continental United States. The Bureau has more than a score of projects in construction, nearly 40 in operation.

News from the Field

ANNOUNCEMENT is made by the Aurora Pump Co., of Aurora, Ill., that Frank S. Main and Lionel W. Claypool, both of whom have resigned their positions with Micro-Westco to become President and Vice-President, respectively, of the Aurora Pump Co. Mr. Main has been vice-president in charge of sales for the Westco Pump division of Micro-Westco, and was previously, for many years, general manager of the Westco Pump Corp. Mr. Claypool, who was graduated in engineering at Purdue University, has been identified with the Westco organization for the past 10 yr. He has been interested in both sales and engineering phases of the business and is credited with important contributions to the efficiency increase of turbine-type pumps widely used in industrial applications.

LINK-BELT Co., Chicago, announces the appointment of Erwin A. Wendell as district sales manager, with headquarters at 317 N. 11th Street, St. Louis, Mo. Mr. Wendell who has been connected with Link-Belt since 1918, succeeds Howard L. Purdon, who has been transferred to assume sales responsibilities in Chicago territory.

EXPANSION of the metallurgical staff of the International Nickel Co., Inc., has added the following members as announced by A. J. Wadhams, vice-president.

Charles H. Lindsley, Ph.D., Princeton, and for the past 2 yr. with the Biochemical Research Foundation in Philadelphia, will specialize in application of physico-chemical methods of studying corrosion phenomena, carrying on the work in the laboratory at Bayonne, N. J. Donald J. Reese, B.S., in chemical engineering, Univ. of Mich., and formerly with Whiting Corp., will conduct research on cast iron at the laboratory. Frederick G. Sefing, B. S., Lehigh and M.S. Penn State College, formerly Assistant Professor of Metallurgy at Mich. State College, will also be engaged in research on cast iron at Bayonne. Richard F. Barnes, Jr., B.S. in Chemical Engineering, Mass. Inst. of Technology, and for 3 yr. employed in research and production of organic plastics, will be available from the New York office, for problems on the use of Monel, Nickel and Inconel where resistance to corrosion is essential. Carl Rolle, Penn. State College and M.M.E., Mass. Inst. of Technology, will be available to give aid on mill product fabrication problems.

IN THE CONSOLIDATION of the Mechanical Operating Division and the Mechanical Engineering Division of the Motive Power Department of the Interborough Rapid Transit Co. of New York, Herbert S. Reynolds has been appointed mechanical engineer in charge of the consolidated divisions. In this position he is responsible for the mechanical engineering, maintenance and operation of the company's two power stations which have a generating capacity of nearly 400,000 kw. and generate over a billion kilowatt hours of electric power per year.

THEODORE MAYNZ, formerly with the Cleveland Electric Illuminating Co. and a consulting engineer in Cleveland, Ohio, has recently joined the staff of Gibbs & Hill, Inc., consulting engineers of New York City, as power plant engineer.

JAMES M. GUY has been promoted from Assistant Chief Engineer to Chief Engineer of the Erie City Iron Works, Erie, Pa. Mr. Guy is a graduate in engineering of the Alabama Polytechnic Institute and has been with the company since 1927.

GERALD DITTMAN, a mechanical engineer for the Utilities Power & Light Corp. of Chicago, Ill., since 1929, has been placed in charge of the Chicago engineering office of the Indianapolis Power & Light Co., one of the corporation's subsidiaries. The office is located at 327 S. La Salle Street.

Mr. Dittman is 37 yr. old and received his technical education at Armour Institute

of Technology. Previous to his connection with the Utilities Power & Light Corp., he was for 9 yr. connected with Neiler, Rich & Co., consulting engineers of Chicago and has therefore a wide experience in design, construction and test of both industrial plants and central stations.

THE SUPERHEATER Co. has transferred to Combustion Engineering Co., Inc., certain functions and personnel with a view to promoting closer coordination in handling the details of complete steam generating units, and thereby to better serve the industry. This concerns the sales, engineering and servicing of "Elesco" superheaters and economizers for stationary plant installations, the manufacture and inspection of which will be handled, as heretofore, at the East Chicago Works of The Superheater Co.

A.S.M.E. Officials at Franklin Institute

In addition to modern mechanisms, this half-size scale model of James Watt's high-pressure, double-acting Sun and Planet condensing engine attracts wide attention from all engineers who inspect it in the Hall of Prime Movers of The Franklin Institute, Philadelphia. Reading from left to right: Henry S. Harris, former chairman of the Philadelphia Section, American Society of Mechanical Engineers; James H. Herron, Cleveland, Ohio, president of the A.S.M.E.; Henry Butler Allen, secretary and director of The Franklin Institute, and J. P. Harbeson, Jr., present chairman of the A.S.M.E., Philadelphia Section.

CRANE CO., in forwarding its plan to provide closer relations with the trade, announces establishment of the East Central district in charge of C. S. Pitkin, who has been manager of Pittsburgh branch since 1922, and the Southeastern district, in charge of J. G. Johns, at Birmingham since 1920.

C. S. PITKIN

At Pittsburgh, H. M. Moss succeeds Mr. Pitkin. At Birmingham, F. D. Morrison succeeds Mr. Johns. F. W. Zander retires from Buffalo on account of ill health and G. E. Anderson of the Lima branch takes his place as manager, E. R. Henning succeeding Mr. Anderson. H. L. Wood of Sioux City, Ia., who retires because of ill health, is succeeded by T. R. Brady from the Rockford, Ill., branch, while R. E. Doherty of Portland, Ore., will take charge of the Rockford branch. S. S. Day at Sacramento, Cal., retires

J. G. JOHNS

from active duty to become special representative and E. B. Moor will become manager at Sacramento. E. T. Rowe from the Syracuse branch becomes manager at Boston, to succeed T. H. Dawson, Jr., who is leaving the company, A. H. Buck from the Pittsburgh branch becoming manager at Syracuse.

B. J. BRUGGE, who for 2 yr. has been assisting in applications of electric welding of pipe lines in Persia, and as consulting engineer on welding in Great Britain, has been appointed to the sales staff of the Lincoln Electric Co. in its Los Angeles office. Besides Mr. Brugge, the personnel in that office now includes G. S. Parsons, C. L. Stocker, C. O. Conzett, W. R. Smith.

CUTLER-HAMMER, INC., announces appointment of T. D. Montgomery as manager of its Foreign Sales division. He has had long experience in application of the company's products and their distribution and will strive for closer contact and service with customers in foreign countries.

Arc Welding Papers Competition

TO STIMULATE study of arc welding, The James F. Lincoln Arc Welding Foundation is offering awards totaling $200,000 for papers dealing with this subject. The competition will be separated on major divisions of the industry, Automotive, Aircraft, Railroad, Watercraft, Structural, Furniture and Fixtures, Commercial Welding, Containers, Welderies, Functional Machinery, Industrial Machinery. Each major division will be subclassified, so that for each subdivision there will be five awards of $700, $500, $300, $200 and $150. For each major division, four papers will be selected to receive additional awards of $3000, $2000, $1000 and $800. From the 11 winning papers will be chosen four to receive main prizes ranging from $10,000 to $35,000, the winner of the grand prize receiving not less than $13,700.

Papers submitted must describe a redesign of a machine or structure so that arc welding may be used in its construction, or a new design which utilizes arc welding, the description showing how a useful result can be achieved by arc welding which was impractical or less well done by other methods. Each contestant must have participated in work upon which the subject matter of his paper is based and must give his exact relation to that work and to the producing organization. A paper may be presented by any one person or by a group of two or more, but each contestant, whether individual or group, may enter only one paper.

Papers must be filed in duplicate by June 1, 1938, with A. F. Davis, Box 5728, Cleveland, Ohio, from whom full particulars as to subclassifications and awards may be obtained.

For the Engineer's Library

ELECTRICAL ENGINEERS' HANDBOOK, ELECTRIC COMMUNICATION AND ELECTRONICS, by Harold Pender, Ph.D., Sc.D., Editor-in-Chief, Knox McIlwain, B.S., E.E., Associate Editor-in-Chief. Published by John Wiley & Sons, Inc., New York City, 1936; third edition, 1122 pages, size 5½ by 8½ in., flexible binding. Price $5.

This is the companion volume to the Electrical Engineers' Handbook Power Volume, a review of which was presented on page 740 of the December, 1936, issue. As its title implies, this volume covers the whole field of communication as a unit. It includes telegraphy, telephony, radio broadcasting, point to point radio telephony, facsimile transmission and reception, public address systems, sound motion pictures, aviation radio and television. It gives complete information on electronic control systems for manufacturing processes, theatre lighting, welding, landing of airplanes, etc. Material is arranged in tabular form with the mechanical and electrical properties listed with each material so that all information about the material is available at a glance. The first section of the book contains complete mathematical tables, etc., logarithms, trigonometric, exponential and hyperbolic functions, decibels, etc., and in the section dealing with electron tubes, exhaustive tables are given, including the new metal tubes, thyratrons, photo-sensitive, cathode ray and x-ray tubes.

This book constitutes Volume 5 in the Wiley Engineering Handbook series. In making plans for new editions of the Wiley Handbooks in mechanical and electrical engineering, a new idea was agreed upon by an advisory board of editors responsible for the issue of the new handbooks. This idea was that the fundamental material underlying all engineering was to be published in a separate volume, and secondly, that the existing handbooks to be revised were to be issued in several volumes containing material closely related to the specialized branches of engineering. As a result, these new engineering handbooks have been published. The first, Eshbach's Handbook of Engineering Fundamentals.* This new book on electric communication, therefore, is the 5th book of that series and the second devoted to electrical engineering. The material in each of the 17 sections into which the book is divided is presented with notable clarity and even though this volume is devoted to the subject of communication, the material in it is by no means of interest only to those in the communication field. Much of the material should be of interest to power men, especially those sections relating to the general subject of electronics. The two volumes, Vol. 4 and Vol. 5, should be a distinct asset to any electrical engineer's library.

THERMODYNAMICS. By Stanton E. Winston. Published by the American Technical Society, Drexel Ave., at 58th St.,

* A review of this book was published on page 671 of the November issue.

Chicago, Ill. Size 6 by 8 in., 174 pages, cloth bound. Price $1.50.

Engineers interested in such fields as air conditioning, Diesel engineering, refrigeration and steam power plants require a knowledge of the fundamental principles of engineering thermodynamics. These must be broad in their application without complicated mathematics and this book accomplishes that in a very concise and logical manner.

Elimination of calculus makes it necessary to include some formulas without a complete derivation, but this does not detract from the practical nature of the book. Discussion of fundamental principles involved, is followed by laws of ideal gases, thermodynamic processes for ideal gases and various heat engine cycles, including the Carnot, Lenoir, Joule or Brayton, Otto and Diesel. The book is divided into 9 chapters, each of which is followed by a large number of practical problems. The answers to these problems are given so that the reader or student in working them will have a check on the accuracy of his calculation and application of principles.

MECHANICAL WORLD YEAR BOOK. Published by Emmott & Co., Ltd., 31 King Street West, Manchester 3, England. Size 4 by 6 in., 360 pp., cloth bound. Price 1/6 net (about 40c).

Each year this well known book is revised and brought up to date. It covers comprehensively the field of mechanical engineering, main divisions are: internal combustion engines, steam turbines, condensing plants, steam boilers, superheating, steam engines, elevators, pumps, compressors, etc. There are also sections on metals and alloys, machine tools and pressures. This year a new section has been added on tooth gearing, giving detailed and comprehensive data on each style of gear in use for engineering purposes.

ELEMENTS OF ELECTRICITY. By William Esty, Robert A. Millikan and Wynne L. McDougal. Published by the American Technical Society, Drexel Ave. at 58th St., Chicago, Ill. Size 5½ by 8½ in., 244 pp., cloth bound. Price $2.

For beginners the study of electricity is often discouraging because most of the available texts are too technical and not easily understood by the uniniated. This book is intended primarily for beginners, requires no previous electrical knowledge and the essential fundamentals are illustrated largely by hydraulic analogies which are already familiar.

The contents include: magnetism, electricity, elementary circuits, Ohm's law, series and parallel circuits, light and power circuits, bell and signal systems, induced currents, transformer construction and storage batteries. The authors are men who are daily teaching electricity to students in class rooms, but, the arrangement and simplicity of the text is such that the book may be easily understood by engineers or students studying at home.

A.S.T.M. Tentative Standards (1936 Edition), published by the American Society for Testing Materials, 260 S. Broad St., Philadelphia, Pa. Size 6 by 9 in., 1390 pages. Price, $8.00 cloth bound, $7.00 paper bound.

The present edition contains 264 tentative specifications, methods of test and definitions of terms covering widely used engineering materials. A large number of the standards are included for the first time, having been approved during 1936. The standards cover ferrous metals, nonferrous metals, cement and ceramic materials, paints, varnish, etc., petroleum products, road materials, rubber products, miscellaneous and general testing methods.

THE ELECTRIC STORAGE BATTERY CO., Philadelphia, Pa., has recently issued Bulletin No. 204, entitled Exide Batteries for Control Bus Operation. This is a well illustrated 16-page booklet containing full technical and engineering data on the application of storage batteries in power plants for control purposes.

ROLLER-SMITH CO., 233 Broadway, New York, has just issued Catalog 11, Section 2, covering a new device, the "Hipot" Insulation tester, a portable outfit for live line testing of porcelain insulators for voltages up to 132,000 v. and higher.

CATALOG No. 899, superceding Bulletins 899 and 899A, on C. P. Universal Electric Tools has just been published by the Chicago Pneumatic Tool Co., 6 East 44th St., New York, N. Y. This is a well illustrated 48-page catalog giving complete information and data on a variety of port able power tools.

PALCO BARK used as insulating material, especially for cold storage service, is described in a bulletin issued by The Pacific Lumber Co., 10 Bush St., San Francisco, Cal. It is made from the bark of the Redwood tree and at 6.72 lb. density has a termal conductivity coefficient of 0.258.

PUMP DATA, covering all standard types and sizes, also special designs, accessories and engineering data on flow of liquids, pump piping and wiring, capacities, operating costs, special uses and mathematical tables, is the title of a convenient book of 233 pages, issued by Economy Pumping Machinery Co., 3431 W. 48th Pl., Chicago, Ill. Convenient arrangement and indexing make this book especially handy for reference. Copies may be had by readers on a request written on their company's letter head.

NORBLO BAG TYPE dust arresters are described in bulletin No. 163-1 recently issued by The Northern Blower Company, 6409 Barberton Ave,, Cleveland. This bulletin illustrates and describes this type of dust collector, also gives tables of dimensions and sizes of the manufactured equipment.

"A MANUAL of Factory Lighting Practice" which provides the plant operating executive with a complete treatise covering the commonly encountered problems of factory lighting and their correct solution, has been published by the Benjamin Electric Mfg. Co., Des Plaines, Ill. It contains authoratative, engineering information on practical, easy-to-apply methods of fitting the lighting to the seeing requirements of each individual operation in the plant. The manual is written for the executive who wants detailed instructions on how to plan his lighting to the seeing needs of each individual operation in his plant. The publication is free to plant executives who request it.

CHEMISTRY of water, correction, is treated in the Third Edition of "Water Analysis, Methods — Chemicals — Apparatus" (revised to October 1st, 1936), published by W. H. & L. D. Betz, Chemical Engineers and Consultants, 235 W. Wyoming Avenue, Philadelphia, Pa. This interesting 32-page book of facts may be had by those who are held responsible for water conditions.

ALEXANDER BROS., INC., Philadelphia, Pa., has recently issued its catalog No. A-116 dealing with Alexander leather products for every industrial purpose. The catalog contains a great amount of technical information together with numerous tables giving horsepower ratings of belting as well as a great amount of other useful data on other products.

THE B&W DIRECT-FIRING Pulverized-Coal System, is the title of a new booklet just issued by The Babcock & Wilcox Co., 85 Liberty St., New York, N. Y., which is a presentation not merely of B&W equipment but of the direct-firing pulverized-coal system from bin to burners. The advantages of this system in reliability, efficiency, ease of operation, and safety are clearly stated. Such important features of the Type B pulverizer as sustained high fineness and capacity, low maintenance, and reliability are also presented.

WHICH END? is the title of a booklet sent out by Appalachian Coals, Inc., of Cincinnati, giving hints on smokeless firing by the alternate method in order to ensure a comfortably heated home and get full value from every dollar spent for fuel.

HOME and Auto Repairs with Smooth-On are detailed in a booklet sent out by Smooth-On Mfg. Co., Jersey City, N. J. It covers cracks in radiators and piping, tightening loose parts, filling holes in floors and the like.

AN ALBUM OF FAMILIAR BELTS, a folder containing 25 reproductions of photographs taken in the field and in the factory has been released by United States Rubber Products, Inc., 1790 Broadway, New York City. These pictures show interesting and unusual installations of transmission belts in a variety of industries, as well as a number of exceptional studies made by Margaret Bourke-White, chief photographer for Life, the new picture magazine, at U. S. Rubber's Passaic Laboratory and Factory.

ALEMITE Controlled Lubrication, issued by Stewart-Warner Corp., Chicago, Ill., presents in 56 pages the line of fittings and equipment for application to industrial machinery.

FIFTY YEARS OF EXPERIENCE is a new and unusual 24 page bulletin just issued by the Goetze Gasket & Packing Co., Inc., New Brunswick, N. J. Design and manufacture of modern gaskets for standard and special requirements of sealing joints against temperature, pressure and corrosion are explained and illustrated by well selected photographs.

BAYER BALANCED VALVE soot cleaners, their design, construction, application and installation, are shown in a 24 page bulletin, No. 107, in three colors just issued by The Bayer Co., 4067 Park Ave., St. Louis, Mo. This is known as Bulletin 107.

THE STERLING crankless, opposed piston, oil burning engine is described in a recent bulletin issued by the Sterling Engine Co., Buffalo, N. Y. Construction, operating principles and application of the engine are described in detail.

CURRENT INPUT CONTROLLERS for furnaces, ovens, and other electrically heated equipment are described in a new bulletin, G-12, issued by Automatic Temperature Control Co., Philadelphia.

SCRUBBERS AND SEPARATORS for gas, oil, air, vapor, steam and water, together with feedwater heaters and mixer heads are covered in a new bulletin, The Master Line, issued by the Master Separator & Valve Co., 607 S. Hill St., Los Angeles.

Power Plant Construction News

Calif., Riverside—Board of County Supervisors, Riverside, has plans for new one-story boiler plant, 60x100 ft., at local county hospital. Cost about $50,000, with equipment. Bids are scheduled to be asked soon. G. Stanley Wilson, Mission Inn, Riverside, is architect.

Conn., Bristol—E. Ingraham Co., North Main Street, manufacturer of clocks and clock mechanisms, plans installation of electric power equipment in new one and four-story additions to plant. Entire project will cost over $75,000. Work will begin soon.

Conn., Hartford—Connecticut Light & Power Co., Hartford, has approved an appropriation of $5,000,000 for expansion and improvements in generating plants, power substations, transmission and distributing lines during 1937. A considerable part of program will be carried out during the spring and summer.

Kan., Goodland—Common Council has plans under way for new municipal electric power plant. Cost estimated at $200,000, with equipment. A bond issue in such amount is proposed to handle cost. E. T. Archer & Co., New England Building, Kansas City, Mo., are consulting engineers.

Ky., Lexington — Richmond Water Commission will receive bids until March 11 for pumping machinery and auxiliary equipment for new waterworks station. Also for 500,000-gal. capacity elevated steel tank and tower. J. S. Watkins, Citizens Bank Building, Lexington, is consulting engineer.

La., New Orleans—Falstaff Brewing Corporation, 3684 Forest Park Boulevard, St. Louis, Mo., plans installation of power equipment in new addition to branch brewery at 2600 Gravier Street, New Orleans, including improvements in present plant. Property was acquired recently. Entire project will cost about $150,000. Bendernagel & Cazale, 8 Marlborough Gate, New Orleans, are architects.

Mich., Cadillac—B. F. Goodrich Co., Akron, Ohio, plans installation of electric power equipment in new branch rubber mill at Cadillac, where former plant of Acme Motor Truck Co., has been acquired, totaling about 100,000 sq. ft. floor space, and will be remodeled and equipped for automobile tire, tube and kindred rubber products production. Entire project estimated to cost over $100,000.

Mich., Newberry—Robbins Flooring Co., Rhinelander, Wis., plans installation of power equipment in connection with rebuilding of portion of wood flooring mill at Newberry, recently destroyed by fire. Loss estimated over $300,000.

Mich., Ypsilanti—United Stove Co., plans installation of power equipment in connection with expansion in plant; a new electric lighting system will be installed. Company has arranged financing through sale of stock to total over $200,000, considerable portion of proceeds to be used for purpose noted.

Mich., Zeeland—City Council has plans under way for a new municipal electric power plant. Cost about $90,000. Ayres, Lewis, Norris & May, Ann Arbor, Mich., are consulting engineers.

Mo., Kansas City—Crook Paper Box Co., 906 East Nineteenth Street, plans installation of electric power equipment in new one-story paper box and container plant, 200x275 ft., on Tenth Street, near Burlington Avenue. Entire project will cost close to $100,000. George B. Franklin, 405 East Thirteenth Street, is architect.

Mont., Great Falls—City Council is considering new municipal electric power plant and will employ a consulting engineer to make surveys and estimates of cost. A. J. Fousek, Mayor, is active in project. Arthur J. Cook, city engineer, will be in charge.

Neb, Kearney—State Board of Control, Capitol Building, Lincoln, Neb., L. D. Hart, secretary, plans new power plant at state hospital at Kearney. Cost about $45,000. Appropriation in that amount is being arranged.

Neb., Omaha—Armour & Co., Union Stock Yards, Chicago, Ill., plans installation of power equipment in new additions to meat-packing plant at Thirtieth and Q Streets, Omaha, consising of three buildings, three, four and six-story, respectively. Entire project will cost close to $700,000.

Neb., Omaha—Metropolitan Utilities District, Eighteenth and Harney Streets, plans extensions and improvements in artificial gas plant at Twentieth and Center Streets, including installation of boiler units and other equipment. Proposed to begin work soon.

N. Y., Brooklyn—Hall Street Cold Storage Warehouses, Inc., 14 Hall Street, plans new six-story cold storage and refrigerating plant on site in vicinity of present plant at 55-57 Washington Avenue, recently acquired. Entire project will cost over $150,000, with equipment. Company is a subsidiary of Frederick Figge Co., same address.

N. C., Charlotte—Water Department plans installation of motor-driven pumping machinery and accessories, chemical feed machinery and other equipment in connection with extensions and improvements in municipal water system. Proposed to hold special election in April to approve bond issue of $1,365,000 for entire project. Robert & Co., Bona Allen Building, Atlanta, Ga., are consulting engineers.

N. C., Lenoir—Caldwell Mutual Electric Corporation, Hunter Martin, attorney and representative, plans electric power plant in connection with rural electrification system in several counties. Fund of $1,070,000 has been secured through Federal aid for entire project. Proposed to begin work soon.

Ohio, Cleveland—Otis Steel Co., 3341 Jennings Road, plans installation of electric power equipment in connection with expansion and improvements in local Riverside mill. Entire project will cost over $2,000,000. Financing is being arranged. Proposed to begin work early in the spring.

Ohio, Cleveland—Steel And Tubes, Inc., 224 East 131st Street, plans installation of electric power equipment in new additions to steel tubing mills. Entire project will cost over $150,000. Company is a subsidiary of Republic Steel Corporation, Republic Building, Cleveland.

Ohio, Rossford—Libbey-Owens-Ford Glass Co., Nicholas Building, Toledo, Ohio, has plans maturing for expansion and improvements in steam power house and water intake system at sheet glass plant at Rossford, to include installation of new high-pressure boiler unit and other equipment. Entire project will cost close to $600,000. Stone & Webster Engineering Corporation, 49 Federal Street, Boston, Mass., is engineer.

Ohio, Springfield—Ohio Edison Co., Springfield, plans call for bids about April for extensions and improvements in electric generating plant on Mad River, to include installation of new high-pressure boiler units and accessories, turbo-generator unit and auxiliary equipment. Extensions will be made in transmission lines. Entire project will cost close to $2,000,000. Company engineering department, Commonwealth & Southern Corporation, Jackson, Mich., is in charge.

Pa., Apollo—Apollo Steel Co., plans installation of electric power equipment in new addition to mill at North Apollo, including hot strip mill unit. Entire project will cost close to $2,000,000. A. M. Oppenheimer is president.

Pa., Pittsburgh — Carnegie-Illinois Steel Co., Carnegie Building, plans expansion and improvements in electric power station at Edgar Thomson Works, with installation of additional equipment for large increase in present capacity. Work will be carried out in connection with new mill units at plant, entire project to cost close to $15,000,000. Work will require over 12 months for completion.

S. C., Hartsville—Hartsville Print & Dye Works plan installation of power equipment in connection with expansion and improvements at textile mill. Cost about $40,000.

Va., Front Royal—Viscose Corporation of Virginia, Roanoke, Va., plans installation of electric power equipment in new multi-unit rayon mill at Front Royal, where large tract of land has been acquired. A power house will be built. Entire project will cost over $1,000,000. Company headquarters are at 200 Madison Avenue, New York, N. Y.

Wash., Port Angeles—Port Angeles Plywood Co., care of H. H. Balch, Port Angeles, recently formed by Mr. Balch and associates with capital of $800,000, plans installation of electric power equipment in proposed new plywood mill on local port dock. A power house will be built. Entire project will cost over $100,000.

Wash., Spokane—Water Department, A. Lindsay, superintendent, plans early call for bids for two motor-driven pumping units with capacity of 16,000,000-gal. per 24 hours, and auxiliary equipment, for installation in proposed new waterworks pumping station on Hoffman Avenue, Hillyard district.

Wis., Neenah—Kimberly-Clark Corporation plans installation of electric power equipment in new five-story addition to paper mill. Proposed to begin work soon. Entire project will cost over $400,000. J. S. Sensenbrenner is vice-president.